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HOW INSECTS LIVE

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HOW INSECTS LIVE

An Elementary Entomology

BY

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To

ENTOMOLOGICAL INVESTIGATORS,

too numerous to mention individually, whose patient efforts have brought to us what knowledge we possess concerning the habits of insects, this book is respectfully dedicated.

PREFACE

Most of us study insects chiefly because of their economic relation to us. In the classes which study economic entomology, insect pests are generally considered in relation to the host plant or animal they affect, and the text book which groups the insects according to their hosts is very useful as a manual to be used in agricultural practice after school days are over. We have found that our students almost invariably keep their copies of Slingerland and Crosby, *Manual of Fruit Insects,* Crosby and Leonard, *Manual of Vegetable Garden Insects,* and Sanderson and Peairs, *Insect Pests of Farm, Garden and Orchard,* to use after leaving school.

Courses in which such text books are used do not, however, give the student the necessary fundamental knowledge of insects as a class, unless these courses are preceded by at least a brief general introductory course in entomology. County agents of the farm bureaus, teachers of agriculture, farmers and fruit growers, who lack the training given by the introductory course and have taken only an economic entomology course while in school, are continually expressing the wish that they knew something of the classification and habits of other insects commonly found along with the pests. It seems, therefore, that courses in economic entomology should be preceded by elementary entomology.

The writer's experiences in teaching elementary entomology have led him to believe that students, when beginning to study the subject, confuse short generalized

accounts of several families of insects which they read at one sitting, and that students are unable to recite such accounts intelligently in most cases. The plan used in this book differs from the usual one, therefore, in the use of a few species as types instead of giving many short generalized accounts of families. The types have been chosen with the idea of illustrating the principal habits of the insect group as well as the principal orders of the group. Most of the species chosen are widely distributed over North America and are commonly seen by any observing person.

A splendid mass of literature concerning many species of insects in various orders has been developed by our entomological workers in the past few years, which is found only in scattered papers not available for the average student. Much of such material has been condensed and arranged on the following pages so as to give the student a modern introduction to the habits of insects. Brevity has been a principal aim in order to keep the book within the time limits of schools having quarter-year terms.

Realizing that, unless due regard for the systematic relationship of the species is given, the student will lose the broad conception of the entire insect group, which is so fundamental, the writer has attempted to keep a systematic background throughout the book. The emphasis has, however, been placed on the biological phases of entomology.

Morphology and taxonomy are undoubtedly the only safe foundations for an entomological training, but, when overemphasized, they destroy the interest of the beginners and, to the general student, who will, in most cases, not become an entomologist, they are unnecessary and

often "bitter pills" to take. In an attempt to "sugar coat the pill," the morphology of each structure which is considered has been mixed with the uses of that structure and no special chapter on morphology is given. Likewise the taxonomy has been relieved of its bitter array of technical terms and obscure characters as far as is possible without becoming unscientific. In place of the general morphological description of the insect group a chapter on insect physiology is given in which the writer has attempted to reduce to simple, non-technical terms the essentials of the life processes of insects and incidentally to introduce the structures which take part in each process.

It is suggested that this text may be used either in a course which is to be followed by a separate course dealing with the control of insect pests, or it may be used during the earlier part of a course to precede the principles of control which are given later in the same term. Assigned readings in the text may be supplemented by lectures or explanations in which the experienced teacher introduces his favorite families and shows to the class specimens which will arouse interest in those families far better than brief accounts in the text book. Classroom discussion should be accompanied by laboratory exercises on the elements of structure and classification of common insects. If possible, the student should make his own collection of insects even though he collects only winter forms such as may be found under loose bark, in dead trees, in greenhouses, basements, etc.

A brief and simple key to a selected number of larger groups of common insects, both in their adult and larval forms, is appended for laboratory use. A list of families is given in Chapter XXVII for reference. The instructor

will often mention insects not included in this book and will give the names of the families to which they belong. The student should have the ability to look up those families in Chapter XXVII just as he is able to look up the position of a city on a map in order to orient it.

A chapter on the Phylum *Arthropoda* is included following the discussion of the insects, with the idea that after the student has learned the ways of the insect group he should associate that group in its proper place among the small creatures which are apt to be confused with insects. Emphasis has been placed on the spiders in this chapter, for they are so commonly associated with insects and attract much popular interest, yet are usually neglected in zoological courses.

The writer has frequently sacrificed scientific exactness for the sake of simplicity but has always attempted to create a true impression in the reader's mind. It is hoped that the specialist in entomology will assume that viewpoint if he should chance to read the following pages.

To all of the entomologists whose published papers have furnished the basis of this text, the writer wishes to express his indebtedness. Because of the nature of the book a full bibliography cannot be included. A few references have been selected to guide the students who desire more information than is given in the following pages.

To my wife, Marjorie T. Wellhouse, to Professor and Mrs. Bentley B. Fulton, to Dr. Carl J. Drake and to Dr. H. H. Knight who have read parts of the manuscript and offered valuable suggestions for its improvement, to Miss Dorothy Beam and Miss Dorothy Craven who have aided in the preparation of the manuscript, a reward of gratitude is extended.

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WALTER H. WELLHOUSE,

Ames, Iowa,
August 12, 1925.

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HOW INSECTS LIVE

HOW INSECTS LIVE: AN ELEMENTARY ENTOMOLOGY

CHAPTER I

GENERAL CONSIDERATIONS

Insects are among the most persistent pests in all nature with which men have been forced to contend. Probably every person on this earth has suffered some annoyance due to insect pests. All the way from the lonely eskimo of the frozen north who is bitten by hungry mosquitoes, to the native of tropical Africa, who suffers from sleeping sickness contracted through the bite of a tsetse fly, the insects are everywhere found to be annoying and often dangerous pests of human beings.

From the earliest times insect outbreaks have wrought havoc to men's crops. The Bible (Joel, Chapters I and II), for example, offers a most interesting account of just such an outbreak as we might expect to hear of today in parts of Asia Minor, Northern Africa, Central China or some such places where modern science has not yet affected the agricultural methods. As shown by the biblical accounts and other accounts as well, in early times men considered insect outbreaks to be sent by the Lord as punishment for their sins. The only resistance to the insect hordes which men dared to offer then was in the form of prayers for deliverance.

With the growth of scientific research, men are gradually becoming able to control some of the natural forces which affect their welfare. We are not so helpless in the times of insect plagues as formerly. The farmer can now call in the professional entomologist to advise him how to save a crop, much the same as he can call in a physician to save his son, or a veterinarian to save his horse.

The scientific study of insects probably did not attract much notice until, in the seventeenth century, men like Swammerdam of Holland and Malpighi of Italy, carefully dissected such insects as the honey bee and silkworm to settle the question as to whether insects have stomachs, brains, blood, etc., like larger animals. The following century brought the development of systematic classification of insects. Classification began to develop in the eighteenth century under such men as Linnæus of Sweden and Fabricius of Denmark. The study of insect anatomy and classification occupied most of the field of entomology until the last half of the nineteenth century when, aroused by the growing severity of insect damage and especially by several very severe grasshopper plagues in the Mississippi valley, the United States government and the state experiment stations began to provide for the study of insect control and professional entomologists began to appear. Until that time most of the men who studied insects did so as a pastime aside from their regular work as physicians, school teachers, etc.

The study of insect control (known as Economic Entomology) has since that time grown much faster than the older phases of entomology. From a force of less than one hundred entomologists at the beginning of the twentieth century there has developed a force of over a thou-

sand by 1925 in our country. While economic entomology has grown faster in the United States, nevertheless it is becoming widely recognized as a science throughout all countries where scientific agriculture has become established and the scientific application of insect control measures is now a part of all progressive community programs. The "bug chaser" is no longer such an object of curiosity and contempt as he was formerly, when the general public was ignorant of the value of his work.

Conservative figures based on estimates of many authorities indicate that insects take a toll of at least 10 per cent of all our crops each year and in unusually severe cases they may take an entire crop. In the United States alone the normal annual insect loss amounts to billions of dollars. In addition to our property losses there are untold losses of human health due to insect-borne diseases such as malaria, typhoid and dysentery, which must be attributed largely to insect pests which spread these diseases. Thus, when it is realized that insect control is as important a factor in efficient crop production and in human health as are many other factors, such as drainage, weed destruction, improved varieties, sanitation, etc., it is then easy to explain the rapid growth of economic entomology.

In spite of the growth which has taken place in the study of insect control and the successful means which have been devised for destroying some of our worst insect pests, our losses due to insects are continually increasing. Why? Such authorities as Dr. L. O. Howard, Chief of the United States Bureau of Entomology, attribute the increasing losses to the advance of civilization. As we bring more and more wild land into cultivation we reduce the number and kinds of plants growing on it.

We cover each field with thousands of plants belonging to one species, such as corn, wheat, potatoes or apples. Each hill of corn or potatoes is planted where dozens of wild plants grew before. Insects which formerly had dozens of plants to browse upon now congregate on the few tender ones which have been substituted and often damage or destroy them. The kinds of insects which find the new plants distasteful disappear eventually, while the kinds which can thrive on them continue to multiply as fast as their food supply multiplies until some check is put upon them.

Another reason for the continual increase of insect pests is that we are importing more and greater variety of plants, animals and their products from all parts of the earth as civilization spreads. Accompanying the spread of plants and animals has come the spread of the insects which live upon them, and thus many of our worst pests, such as the Hessian Fly, European Corn Borer, and San Jose Scale, are accidentally introduced from foreign lands. Of late years a large corps of entomological inspectors has been maintained to examine for insects all imported products liable to harbor pests, and many plants are entirely excluded from the country because of the danger of increasing our pests.

This continual increase in insect damage therefore demands a much greater development of economic entomology if we are to avoid even greater losses than the insects have caused in the past. Man has gained his place of dominance in nature by his wits and he must outwit the insects if he is to hold his place. If he does not learn how to control them his food may become their food more and more as the years go by. The application of chemical control measures such as poisons, attractants and repel-

lents; the use of physical means such as electric charges, ultra violet rays, excessive heat and cold; the use of biological agents such as parasites and diseases to destroy insect pests, all await further development. But the employment of economical control measures must be based upon a knowledge of the habits and life processes more complete than we now have of most insects. The failure or impracticability of many control practices in insect work has been due to insufficient knowledge of what each different kind of pest will do under varying conditions. Comparatively few of the habits of insects have been investigated yet. The most studied insect is the honey bee. It has been studied for thousands of years and yet the experts in bee-keeping are constantly seeking to learn some of its unknown habits. This does not mean that entomologists have been asleep, for there is probably as much known about insect habits as about the habits of all other kinds of animals combined. But the number of different kinds of insects is far greater than of all other kinds of animals, so the entomologists have much more to learn. The growing number of entomologists and the improvement in methods of observing insects are enabling us to learn much faster than ever before the secrets of the insect world.

In addition to the need of further research in entomology to originate more and better practices for insect control, there is a great need of informing the farmer, stockman, fruit grower, forester, sanitary officer and other citizens, in the fundamentals of insect habits and control so that they can successfully use the control measures recommended by experts. Just as the average citizen after learning the elements of human physiology and hygiene can take more intelligent care of his health and

avoid useless or expensive patent medicines, so also can he learn enough of the principles of insect life and control to avoid wasting time and money on useless or extravagant methods of insect control.

Although most insects must be considered as pests because their ways clash with our ways, still we must not forget that there are useful insects also. The honey bee brings many millions of dollars annually to the bee-keepers, and the silkworm brings hundreds of millions to the countries which specialize in silk production. The lac insects of the tropics produce a resinous excretion from which our shellac is made, and China-wax is also the excretion of a scale insect. Thousands of other species of insects are indirectly useful to us because of their habit of destroying other insects either as predators which devour weaker insects or as parasites which gradually consume larger insects. A verse by De Morgan runs:

"Great fleas have little fleas on their backs to bite 'em,
And little fleas have lesser fleas, and so ad infinitum,
And the great fleas themselves, in turn have greater fleas to go on;
While these again have greater still, and greater still, and so on."

Although the parasites of insects are not fleas but parasitic flies and wasps, the general idea of the poet is correct. The number of insects annoying us would be far greater if other insects did not destroy many of the pests.

Numerous biologists interested primarily outside the field of entomology have used insects extensively to learn general principles of life, for the great variety in insect forms and habits offers abundant material for study. The fruit fly, *Drosophila* (page 215), has been for many years the standard type for laboratory study

by students of genetics, because of the rapid succession of its generations, and its variable characters. Students of animal coloration have drawn their material largely from insects. The study of animal sociology is greatly enriched by studies of colonial life among ants, bees and termites. Such problems as utilization of cellulose for food, and other broad physiological problems are being solved by the study of insect physiology. Since the highest degree of intelligence found among invertebrate animals is found among insects, the study of their psychology is gaining interest each year.

In order that we may be able to associate the insects to be studied with their proper Orders in the general classification of insects, which will be considered in a later chapter, it will be well to learn the names of the Orders, which are the major divisions of the Class Insecta, before going further. It should be remembered that not all entomologists have agreed to use the same names of Orders, of Families, of Genera, and some even divide the insects into several Classes. A half-million species so imperfectly known as the insects are bound to cause some difference of opinion among the classifiers. The writer has attempted to choose a rather conservative ground in making the following list of orders. It should be recalled that each Order is composed of Families; each Family of Genera and Species. An estimate of the number of species which have been discovered is given with each order.

CLASS INSECTA

Orders	*Examples or Common Name*
1. *Thysanura* (250)	*Campodea*, "silver fish"
2. *Collembola* (1,030)	Springtails, "snow fleas"
3. *Ephemerida* (450)	May-flies
4. *Odonata* (2,650)	Dragon-flies
5. *Plecoptera* (480)	Stone-flies
6. *Embiidina* (60)	*Anisembia*
7. *Orthoptera* (15,000)	Roaches, crickets, grasshoppers
8. *Isoptera* (500)	Termites
9. *Dermaptera* (740)	Earwigs
10. *Coleoptera* (195,000)	Beetles, weevils
11. *Strepsiptera* (150)	Stylopids
12. *Thysanoptera* (500)	Thrips
13. *Corrodentia* (600)	Psocids
14. *Mallophaga* (1,350)	Bird lice
15. *Anoplura* (80)	Sucking lice
16. *Hemiptera* (21,000)	True bugs
17. *Homoptera* (16,000)	Aphids, scales, leafhoppers
18. *Neuroptera* (2,150)	Aphis lions, ant lions
19. *Trichoptera* (1,600)	Caddis flies
20. *Lepidoptera* (92,000)	Butterflies, moths
21. *Mecoptera* (163)	Scorpion-flies
22. *Diptera* (51,000)	True flies
23. *Siphonaptera* (350)	Fleas
24. *Hymenoptera* (67,500)	Sawflies, parasitic wasps, bees, ants

REFERENCES:

BOUVIER, E. L. *The Psychic Life of Insects* (trans. from French by L. O. Howard), 1918.

CROSBY, C. R., and LEONARD, M. D. *Manual of Vegetable Garden Insects*, 1918.

ESSIG, E. O. *Injurious and Beneficial Insects of California*, 1915.

FELT, E. P. *Manual of Tree and Shrub Insects*, 1924.

FERNALD, H. T. *Applied Entomology*, 1921.

HERMS, W. B. *Medical and Veterinary Entomology*, 1923.

HERRICK, G. W. *Insects Injurious to the Household*, 1914.

HOWARD, L. O. "The Needs of the World as to Entomology" (in *Ann. Ent. Soc. Amer.*), Mch., 1925.

LOCHHEAD, W. *Economic Entomology,* 1919.

O'KANE, W. C. *Injurious Insects,* 1912.

OSBORN, HERBERT. *Agricultural Entomology,* 1916.

PHILLIPS, E. F. *Beekeeping,* 1915.

PIERCE, W. D., and others. *Sanitary Entomology,* 1921.

RILEY, W. A., and JOHANNSEN, O. A. *Handbook of Medical Entomology,* 1915.

SANDERSON, E. D., and PEAIRS, L. M. *Insect Pests of Farm, Garden and Orchard,* 1921.

SLINGERLAND, M. V., and CROSBY, C. R. *Manual of Fruit Insects,* 1914.

WARDLE, R. A., and BUCKLE, P. *Principles of Insect Control,* 1923.

CHAPTER II

INSECT ANATOMY AND PHYSIOLOGY

Insects are among the most highly specialized invertebrate animals and because of their specialization have developed many structures which are peculiarly adapted to the lives they lead. The great variations in the structures of their bodies can best be learned by examining different kinds of insects in the laboratory. We can best consider here the general functions or uses of the principal parts of insects' bodies and incidentally point out what those parts are. We need to learn something of the fundamental life processes going on within the insects in order to understand the external manifestations of their instincts and habits.

Many of the phases of insect physiology are but little known to science yet. Entomologists have been forced to base their control methods on a superficial knowledge of insect habits, due to the lack of existing information on insect physiology. For instance, the control of codlin moth, which is the insect most commonly causing wormy apples, has been based on the habit of the tiny caterpillar's eating a bit of the apple skin when boring into the apple. A poison such as arsenic is sprayed on the apple trees so as to cover the fruit and poison the caterpillar as it bores through the skin. But in many sections of the United States we are unable to predict the time of appearance of the caterpillars, and consequently fre-

quently fail to have the fruit covered with poison at the proper time. The result is a large per cent of wormy fruit. We need to learn the exact life processes of the codlin moth, which lead to the appearance of the caterpillar, and to learn what external influences accelerate and retard its appearance. Then it will be more nearly possible to spray effectively to control codlin moth in every valley and on every hillside.

We may also succeed in attracting flies into a trap by means of a certain bait at one time, while at other times the bait does not attract them. Its attraction may have been due to the presence of some necessary food element which had been temporarily lacking in their diet, or it may have been pressure from crowded eggs in their ovaries which drove the flies to the proper substance on which to deposit eggs, or it may have been due to some other physiological process. Again, some insects are active only during cool temperatures, such as those of spring or fall, and remain dormant all summer. A study of the fundamental life processes in such insects will be necessary before we can account for this behavior, and be able to anticipate their actions with enough certainty to prevent their injuries to our crops.

The number of species of insects is so great that we cannot hope to know the exact physiology of each of them even within the next few centuries, but there is immediate need to study our most important pests enough to understand their habits and to anticipate their actions. The few explorers who have entered the field of insect physiology have set up valuable landmarks which, although scattered, may enable us to gain a bird's-eye view of the field. A brief discussion can be but a general summary of the facts and principles, and

it must be remembered that there are exceptions to all general statements. The following arrangement of topics includes the principal activities of an insect's body:

FUNCTIONS OF THE INSECT BODY

1. Protection (defense against the elements and enemies).
2. Motion and locomotion (movement of parts or of the whole body).
3. Ingestion (the action of taking food into the digestive canal).
4. Digestion (preparation of food for assimilation into the cells of the body).
5. Egestion (elimination of undigested material from the intestine).
6. Excretion (elimination of waste products taken from the cells of the body).
7. Circulation (transportation of materials in the blood stream throughout the body).
8. Respiration (breathing and exchange of gases in the cells of the body).
9. Sensation (reception of stimuli from the outside world by means of the nerve endings at the surface of the body).
10. Coördination (selection of appropriate responses to stimuli by means of the nervous system).
11. Reproduction (production of offspring).
12. Growth (enlargement of the body and formation of new parts).

1. PROTECTION

Insects, like other animals, must have some means of protecting their bodies from the weather and from ene-

mies. The weather affects insects to the extent that they are exposed to it. A leaf-eating caterpillar upon a roadside plant may be knocked to the ground and drowned by heavy rains; it may be blown to the dusty ground on a hot day and die of suffocation as it struggles to get out of the dust; the drought of summer may cause its food plant to wither and become unfit for food; if the temperature of the air drops to a point below which the insect cannot remain active, it must lie dormant until the air warms up again.

On the other hand, a borer living within the stem of a tree is very little affected by rain or wind except as they affect the tree, and sudden changes in temperature do not reach the borer. It is, however, affected by the great seasonal changes in temperature and becomes dormant during winter. An ox warble grub, living beneath the skin of a cow, and a book louse, living in a steam-heated library, are very little affected by wind, rain or sun at any time.

All animals living in exposed situations must have protection against too great an evaporation of water from their bodies. The evaporation must not be so rapid that the internal supply of water cannot be replenished from available food or drink. When you stop to think that living, active protoplasm is largely water and many physiological activities of animals depend on water as a solvent or carrier, then the necessity of avoiding too rapid an evaporation is apparent. Insects, because of their small size, have more surface in proportion to their mass than larger animals, and so there is more danger from evaporation. Some kinds of insects have met this danger by remaining entirely in moist, protected places. If accidentally they become exposed to the evaporation of

sunlight for an hour or so, they die. Some insects leave their retreats only during the night or other periods when the evaporation rate is low, to go out in the open. Others have developed water tight "shells" or coats of closely overlapping scales and hairs to cover the body. Such insects can live in situations exposed to rapid evaporation much longer than unprotected ones can.

Most adult insects, since their business of perpetuating the species requires much roaming about, either by walking in exposed places, or by flying, have a shell-like covering made of *chitin* ($C_{15}H_{26}N_2O_{10}$), a hardened fluid which is secreted in the outer layer of body cells. Chitin is a material somewhat like horn, or the shell of turtles, and protects insects from many enemies as well as from evaporation. Among predatory insects it serves to keep them from eating each other, since their jaws are more suitable to crushing soft-bodied insects. Birds also usually prefer the softer bodies of less chitinized forms as food. All insects have some chitin covering their bodies, but most young forms and some adults have but a thin coat of it.

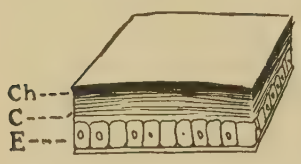


FIG. 1.—Diagram showing a section of body wall of an insect. *C*, cuticula; *Ch.*, chitin; *C*, epidermal cells.

Some insects possess other features which tend to protect them from enemies as effectively as a heavy shell of chitin. The spines and hairs of some species of caterpillars; the horns, antlers and other projections of some beetles; the eye-like spots on wings or thorax of certain moths and beetles, all seem to have aided in the survival of their possessors.

Most insects, as well as most other wild animals, are

protected from enemies by the possession of colors which cause them to blend in with their usual surroundings; consequently those insects are difficult to find unless they are moving. Some insects, such as wasps or bees, can afford to wear colors which make them conspicuous, because they have weapons for their protection and are avoided by any experienced bird or toad or other insect eating animal. Other insects, such as curculios and some of the looping caterpillars, are protected by their habit of remaining motionless as if dead when approached by other animals. A motionless insect is usually difficult to discover and moreover, animals which use insects as food commonly prefer living ones and will pass up those apparently dead. "Playing 'possum," therefore, has developed into an instinct because it resulted in survival of those who played dead most successfully.

2. Motion and Locomotion

Movement of animals is the particular function of muscles and is the result of their contractions and expansions. Insects are well supplied with muscles. A careful estimate of the total number of muscles in a caterpillar, *Cossus lignaperda,* is given as 2,000 by Packard. Comparison with the number of muscles in the human body (approximately 510) shows that the caterpillar has about four times as many muscles as a man. The number of muscles is not the same in all insects, but varies with difference in species and with difference in the stage of development of an insect. No complete counts of the individual muscles in most insects have been made, but we know where the more important sets of muscles are located in most insects.

The two main groups of muscles are: First, those of

the body wall and its appendages; and second, those of the alimentary canal. A few additional muscles belong to the heart and reproductive organs. The most numerous muscles are those of the body wall. Many of them are used to bend or shorten the main trunk of the body, which includes thorax and abdomen, some move the head, some move the jaws or beak, some the antennae, while the most powerful ones move the legs and the wings.

The ends of muscles must be attached to rigid supports of some kind so that the contraction of the muscles will cause movement of the body. Insects have no bones inside their bodies which can be used for this purpose, so their muscles are attached to the hard wall of chitin which covers the outer surface of the body. For instance, a muscle which moves a leg forward has one end attached to the inside of the chitinous covering of the leg and the other end attached to the chitinous covering of the thorax in front of the leg. The contraction of this muscle must pull its two solid attachments closer together and consequently the leg moves forward. The chitin of insects is often called the *exoskeleton,* since it covers the outside and is thus in contrast to the endoskeleton or internal skeleton of the vertebrates.

The question naturally arises of how an insect covered with a rigid layer of chitin can bend its body. Bending is effected even in the most heavily chitinized insects by means of joints or creases where the body wall has remained flexible. The insect can bend much like the mediæval knight in his suit of armor. Chitin is usually thickest where the muscles of wings, legs and jaws are attached and upon those parts of the body which are most exposed.

The muscles of the alimentary canal are arranged in

layers surrounding the entire canal. One layer, the muscles of which encircle the canal, can lessen the diameter of any portion of the canal by contraction of the muscles. Another layer, the muscles of which extend lengthwise along the canal, can shorten the various parts of the canal by contracting. The combined action of both layers of muscles produces the peristaltic movement by which food is passed along the canal toward the rear.

Locomotion in insects is largely by means of legs and wings, although the young of some insects, such as the maggots of flies, have no legs and crawl like worms. All adult insects, except a few parasitic ones, such as scale insects, which remain stationary, have *three pairs of jointed legs* attached to the thorax. The young of most insects (caterpillars, grubs, etc.) have the three pairs of jointed legs which are retained in adult life, and some have in addition several pairs of leg-like props, called *prolegs,* under the abdomen. Many caterpillars have five pairs of prolegs well distributed so that, in walking, the entire body glides along over a surface with no parts dragging. Some caterpillars have no prolegs under the central segments of the body, but have near the rear end two pairs which may be used in conjunction with the three pairs of thoracic legs to produce a looping gait and thus avoid dragging the body. Such caterpillars are usually called "measuring worms" or geometers. The young of many sawflies have seven and some nine pairs of prolegs. Prolegs all disappear when the adult form is attained.

The leg of the adult insect may vary in size and shape with different species but always has the same essential segments (*coxa, trochanter, femur, tibia, tarsus,* see Fig. 2). In leaping insects, such as fleas, grasshoppers and

leaf-hoppers, the hind legs are larger or stronger than the middle and the front legs, and can propel the insect many times its length. In some predaceous insects, such as the assassin bugs, the front leg is the stronger one and is used for capturing prey.

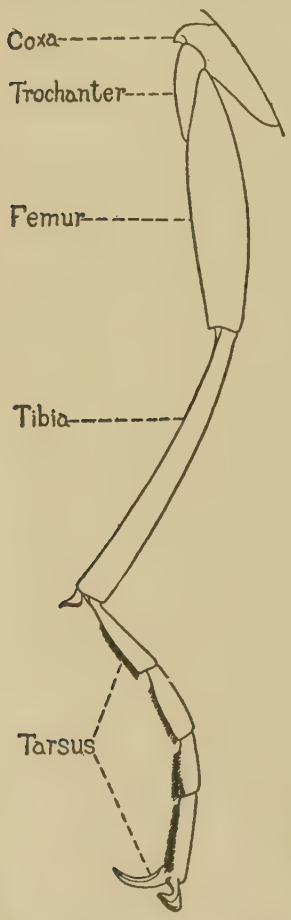


FIG. 2.—Leg of an insect. (From Crosby and Leonard.)

The largest groups of adult insects have wings which have grown out above the thorax. Usually, there are two pairs of wings, but some groups, such as flies and mosquitoes, have only one pair. Beetles, earwigs and some bugs have the front wings heavily chitinized and they lie flat on the body, covering the second pair of wings. The hard shell-like front wings of beetles and earwigs are known as *elytra*, and those of bugs are known as *hemelytra*. Elytra and hemelytra are largely protective in function and are used much less in flight than are the thin, transparent wings which lie beneath them. Although the wings of many insects are as thin as a delicate membrane they are usually strengthened at various places by means of thickly chitinized lines called *veins*, and are often durable, efficient organs of flight. Some dragon-flies fly as swiftly as swal-

lows while capturing smaller insects in the air for food. Hoverflies and humming-bird moths vibrate their wings so rapidly that these insects can remain poised in midair over a flower. Experiments have shown that a bee completes 190 wing strokes per second, and a house fly 330 strokes per second during flight.

3. Ingestion

For convenience in applying insecticides, entomologists have recognized two methods used by insects in devouring their food—chewing and sucking. *Chewing* may here be defined as the act of cutting or tearing solid material with the mouth parts, as a preparation for swallowing. *Sucking* may be defined as the act of drawing food into the digestive canal by alternately collapsing some part of the canal, then opening that part to create a vacuum within, toward which the food flows. The act of sucking is much like the filling of a medicine dropper with liquid. By collapsing the rubber bulb we expel the air from it, then as the bulb expands the liquid climbs up to fill the vacuum created within. Sucking insects may take only liquids or small particles of solid foods carried in liquids. Chewing insects may eat large solid objects as well as liquids. For instance, a leaf-eating caterpillar chews the tissues of a leaf and swallows them. In doing so the caterpillar will eat poisonous material which has been sprayed on the surfaces of the leaf. On the other hand, a plant bug in taking its food from a leaf sucks the sap and soft protoplasm from within the leaf cells, but does not take any of the poison which covers the surfaces, because none of the solid walls of the leaf can enter its mouth. Sucking insects must therefore be killed by other means than sprays containing stomach poisons.

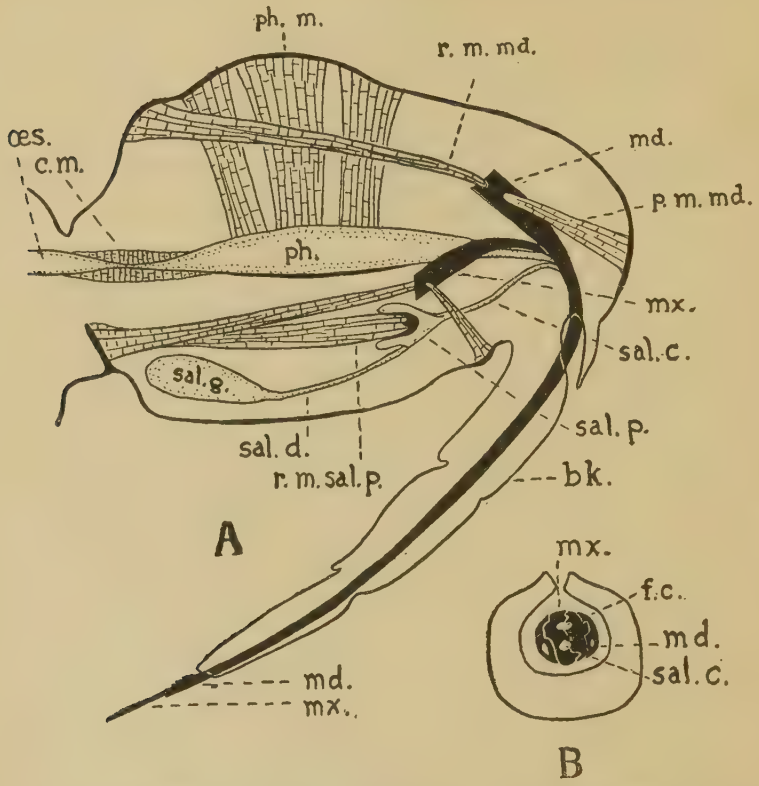


FIG. 3.—*A*, diagram of sucking mouthparts of a bug; *B*, cross section of beak showing how maxillæ fit together forming salivary and food canals. *bk*, beak; *ph*, pharynx; *ph. m.*, muscles which open pharynx; *c. m.*, circular muscles which can close passage at rear of pharynx; *oes*, oesophagus; *mx*, maxilla; *md*, mandible; *p.m.md.*, protractor muscle for pulling mandible forward so that its tip can be used to penetrate skin of host; *r.m.md.*, retractor muscle for pulling mandible back into head; *sal.g.*, salivary gland; *sal.d.*, salivary duct; *sal.p.*, pump for forcing saliva through salivary canal into host; *r.m.sal.p.*, retractor muscle for opening chamber of salivary pump; *f.c.*, food canal which is continuation of pharynx to tips of maxillæ; *sal.c.*, salivary canal.

The structures used by insects for getting food into the digestive canal are known as *mouthparts*. Mouthparts

serve well as an example of the specialization and adaptation of structures which have evolved in insects. There is an endless variety of form to be found in their mouthparts, which are often peculiarly adapted to getting certain foods. The long, lapping tongue of the bee enables it to reach the depths of a flower and find the nectar which most other insects cannot reach. The extremely long snout of a nut weevil is an admirable tool for penetrating the thick husk and shell of a nut and chewing the kernel within. The sharp, strong jaws of a ground beetle are keen weapons for killing and devouring a caterpillar. The beak of an assassin bug is as efficient as a hypodermic needle for piercing the body wall of its victim and sucking out the juices within.

4. Digestion

Very little is known concerning the physiology of digestion in insects. The kinds of enzymes produced in the various parts of their digestive system and the kinds of foods which are digested and assimilated are alike imperfectly known. Field observations have led us to believe that most grasshoppers live on a diet of green plants only, but we have no idea of how much protein they require or whether they require other substances, such as minerals, in small quantity secured from other sources. We occasionally find species of insects living on a single dry concentrated food, such as candy, ground pepper, rice and bolted wheat flour; apparently they continue to grow in these substances without any water except that produced by oxidation of the food which the insects have assimilated.

Possibly some of the enzymes used in the digestive canal of some insects are manufactured in the plants

which are eaten as part of the food and it is also probable that some foods used in insect diets are, as Cleveland has shown in the case of cellulose, digested first by proto-

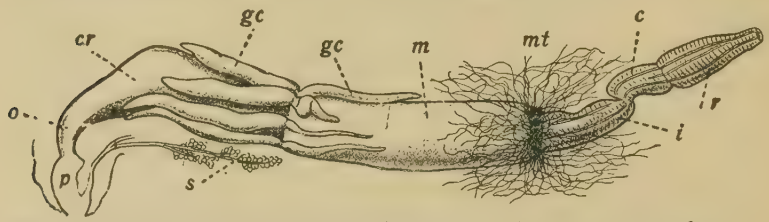


FIG. 4.—Alimentary canal of a grasshopper. *p*, pharynx; *o*, oesophagus; *cr*, crop; *gc*, gastric caeca; *m*, mid-intestine; *mt*, Malpighian tubes; *i*, ileum; *c*, colon; *r*, rectum; *s*, salivary gland. (From Folsom.)

zoans and bacteria living within the insect. It is certain that insects can eat many foods, such as rotting wood, tobacco, wool and pure cellulose, which vertebrate animals are unable to digest, yet we have been unable to

FIG. 5.—Alimentary canal of a moth. *o*, oesophagus; *s*, salivary gland; *c*, food reservoir; *m*, mid-intestine; *mt*, Malpighian tubes; *i*, ileum; *cl*, colon; *cm*, caecum or pouch; *r*, rectum; (From Folsom after Wagner.)

find in insects any such complex organs as liver or pancreas for the manufacture of digestive enzymes. Their digestive systems include fewer organs than ours, yet their digestive power is possibly greater.

The parts of the insect digestive system (Figs. 4 and 5),

have been named largely by comparison with those of the vertebrate digestive system, although the real uses of the parts are largely a matter of conjecture. Any study of the uses of parts has been handicapped by the great lack of uniformity in the insect group. The so-called salivary glands, for instance, which open into the mouth of many insects, have been studied in a few insects. It is stated that in some herbivorous insects the secretion of these glands turns starch into glucose as the saliva of vertebrates does. In some carnivorous beetles the secretion acts on proteids. In the mosquito, the secretion from the corresponding glands is a poison which reacts very differently from saliva when injected into our skin. In the mouth of the worker honey bee some experimenters have found the secretion to be alkaline, others have found it to be acid, while in the bee grub and most caterpillars the same glands manufacture silk.

In general we know that the food after entering the mouth of an insect is passed slowly backward through the digestive canal by peristaltic movement of the canal, and that during this passage it is made soluble by the action of digestive enzymes whether they be produced by organs of the insect or by protozoans and bacteria living peacefully within the canal. The soluble food is then absorbed into the blood stream surrounding some part of the canal and the insoluble or undigested parts of the food are egested.

5. Egestion

In many insects, that portion of the digestive canal known as the *rectum* is permanently enlarged for the storage of indigestible portions of the food such as chitin,

cellulose and chlorophyll until it is defecated. In others the rectum is not a permanent enlargement, but the rear part of the intestine is very flexible and expands or contracts with the contents. One has only to observe a caterpillar devouring a cabbage leaf to note that it defecates little green pellets at very frequent intervals to make room for more of the leaf in its intestine. The honey bee workers, on the other hand, are able to store their feces in the expansible intestine for months at a time and thus keep the hive clean during the winter when they are unable to make flights. The bee grubs, living in the brood cells, and many parasitic grubs which live within the bodies of other insects, have an incomplete intestine; the passage to the rectum not being connected with the mid-intestine until the end of the grub stage. Such insects use mostly prepared, predigested foods and the small amount of waste accumulating in the canal during this period is stored at the rear end of the mid-intestine until the insects can emerge from their restricted quarters.

6. Excretion

Oxidation of foods furnishes the energy for the various activities carried on in the tissues of insects and as a result waste products are formed. These are carbon dioxide, water and soluble organic compounds which will no longer yield energy. Carbon dioxide is removed in respiration. The water formed is carried in the blood to any part of the body which needs it. The organic compounds are carried in the blood until they are extracted by long, slender, kidney-like glands called *Malpighian tubes* (Figs. 4 and 5). These tubes then form and excrete into the intestine, with which they are con-

nected, several insoluble compounds, such as uric acid, urate of ammonium and calcium oxalate, which are the final waste products to be eliminated from the body along with the feces. Malpighian tubes differ in number in different insects. Very commonly there are four or six tubes, but some insects, such as the honey bee and some grasshoppers, have more than a hundred. A few primitive insects have no Malpighian tubes and, according to Folsom, it is supposed that they store their waste products permanently in the fat cells of their bodies. Others are supposed to deposit urates in the outer covering of the body, which is later shed in the molting process. The wastes excreted by Malpighian tubes pass down these tubes into the intestine and the waste substances, because of their insolubility, may remain with the food for some time without being reabsorbed into the blood. They are quite different from the urea of mammals, which is very soluble and must be expelled from the body soon after it is collected.

7. Circulation

The circulatory system of insects in general has two very fundamental differences from that of vertebrate animals. First, the insect's blood is not confined within a system of closed blood-vessels; and second, it is not the principal carrier of the oxygen supply to the organs of the body. How, then, is the blood kept in circulation, and what is the carrier of oxygen?

The blood is pumped forward into the head through a single muscular blood-vessel extending the length of the body in the same relative position as our backbone, and known as the *dorsal vessel.* It is sometimes referred to as the heart. There is a series of valves in the dorsal

vessel which allow the blood to enter from the sides of the vessel, but which prevent the blood within from moving in any other direction except forward. The vessel contracts rhythmically, beginning at the rear end. The end of the vessel in the head is open and the blood flows from it, filling the cavities about the brain; then, due to lower pressure in the cavities of the abdomen, the blood moves backward from the head through the spaces between the organs of the thorax and abdomen.

During its passage backward the blood bathes the organs and tissues, giving food to the cells and absorbing their waste products. As it passes the intestine, the blood takes up digested food which dialyzes into it, and as it passes the Malpighian tubes it gives up wastes to them. Eventually it is drawn into the dorsal vessel and pumped forward again. A few small blood-vessels have been discovered at the bases of legs and antennae in some insects and these vessels, known as *ampullæ,* pump blood into the long, slender appendages much like the dorsal vessel pumps it in the main body.

The blood of most insects is nearly colorless, with a tint of green or yellow. It is composed of watery *plasma* and *white corpuscles,* there being no red corpuscles in insects. A few insects, especially those known as blood worms, have the red pigment, hæmoglobin, dissolved in the plasma and consequently have red blood, but they are exceptional. The plasma in active insects is usually largely water, but, as Muttkowski has shown, contains serum, fibrin, hæmocyanin, wastes and food. The white corpuscles act as scavengers to remove disease germs and broken-down tissues of the body. They also secrete gelatine, which coagulates on exposure to the air and thus staunches the flow of plasma from wounds.

8. Respiration

Air is distributed within the insect by means of a system of air tubes, called *tracheæ* (Fig. 6), which have numerous branches extending among all the tissues of the body, much as the blood vessels ramify among our tissues. The larger tracheæ are, at several places, connected with small openings known as *spiracles,* which penetrate the body wall along both sides of the body, and allow atmospheric air to pass into the tracheæ. The spiracles frequently possess valves which exclude dust and other foreign substances. In the case of a few insects, such as grasshoppers, blow flies, and some aquatic beetles, it has been discovered that some spiracles are used entirely for inhaling air, while others are used only for exhaling it. In the grasshopper, for instance, Lee has found that the first four spiracles on each side of the body are for inspiration while the last six are for expiration.

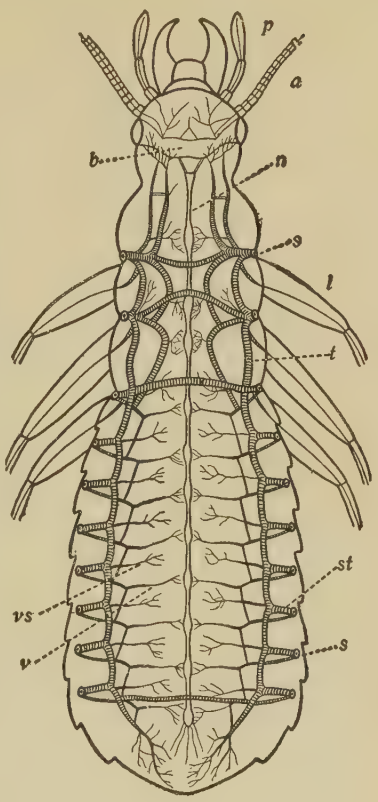


Fig. 6.—Tracheal system of an insect. *a,* antenna; *b,* brain; *l,* leg; *n,* nerve cord; *p,* palpus; *s,* spiracle; *st,* branch of trachea to spiracle; *t,* main trachea; *v,* ventral branch of trachea; *vs,* branch of trachea to viscera. (From Folsom after Kolbe.)

If we observe carefully the breathing of one of the larger insects it is possible to watch the regular expansions and contractions of the abdomen which appear much like the breathing movements of the thorax of a mammal. The thorax of most insects is so completely chitinized and rigid for the attachment of leg and wing muscles that it takes no part in the breathing movement. The abdomen is not so heavily chitinized and has numerous flexible areas which serve as joints where the body wall may be folded. The contractions of the abdomen bring pressure upon some of the tracheæ and tend to expel the air, but there is such great variation in the breathing of insects and so little known about the exact process, that we can give no general explanation of it yet. Swiftly flying insects, which must need a rapid replacement of air in the tracheæ supplying the wing muscles, have expansions of certain portions of the larger tracheæ known as *air sacs*. Pressure from the contraction of the body wall causes some of these air sacs to force air in and out of the tracheæ like a bellows, thus affording a much faster exchange of air than is obtained from ordinary tracheæ.

Insects living in water must either come to the surface to inhale air through their spiracles, or they must have some special adaptation, like gills, for taking oxygen, which is dissolved in the water. No adult insects breathe by gills, but the young forms of several large groups possess gills. Usually, the gills are thin-walled outgrowths of the body-wall; they are hair-like or leaf-like in shape, and have tracheal branches within. Oxygen passes by diffusion into the tracheal branches from the water, while carbon dioxide diffuses in the opposite direction. Such gills are called *tracheal gills* and are

found on the young of may flies, damsel flies, stone flies, some caddis flies, a few beetles and a very few caterpillars. Another form of gill differs from the tracheal gill in having no tracheal branch within but a space where the blood circulates freely inside the thin walls of the gill. These are known as *blood gills* and are found on the young of black flies, midges and some caddis flies. Practically all of the young insects possessing gills lose them and develop spiracles when the adult form is attained.

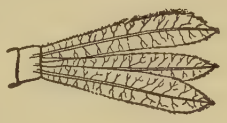


FIG. 7. — Tracheal gills of a damsel fly naiad. (From Folsom.)

It is the opinion of the writer that the hæmocyanin which is constantly found in the blood of insects, acts as the carrier of oxygen from the fine tracheal branches to the individual cells in the tissues and organs, although this has not been proven conclusively yet. Hæmocyanin is decomposed by arsenic, hydrocyanic acid and some other insecticides after they enter the blood and respiration is stopped as a result. From this we may infer that the hæmocyanin is necessary for respiration in insects, and supplements the tracheal system in distributing oxygen within the body.

9. SENSATION

Sense organs are cells, or organized groups of cells, at the surface of an animal's body, and it is their duty to receive stimuli from outside the body so that the animal may become aware of such things as light, sound, odors, etc. Some sense organs contain pigments which respond to light only, and we call them organs of sight. Some contain delicate cords, or membranes, which vibrate in response to sounds, so we call them organs of hearing.

Others are affected by contact with external objects and are called organs of touch; while others located in moistened cavities, where they are protected from evaporation, are affected by chemical solutions and gases. These latter are called organs of taste and smell. On our own bodies we find all of the above-mentioned sense organs are few in number and are concentrated on the head, except the organs of touch, which are scattered all over the body.

In insects, we know little about some of the sense organs, but many of them seem to be located away from the head and often they are scattered rather than concentrated in large organs. The organs of sight—eyes—are always on the head. Adult insects usually have a large *compound eye* on each side of the head, and often they have in addition two or three small *simple eyes* on the front of the head. Caterpillars and many other young insects have several simple eyes grouped on each side of the head and no compound eyes. A simple eye has a single fixed lens and is used simply to distinguish between light and darkness, or to perceive objects at close range. A compound eye has hundreds, or sometimes thousands, of small lenses covering its surface, which is convex and has lenses focused in many directions at once. Each lens makes a separate image and the image produced by the entire compound eye is a mosaic composed of all the separate small images. Compound eyes are said to perceive the form and movement of objects as well as light and darkness.

The organs of hearing are located on various parts of the bodies of those insects on which the organs have been discovered. The grasshopper has an oval organ on each side of the basal segment of the abdomen, under

the wings, and this organ is sensitive to sounds. The antenna of a male mosquito contains organs of hearing. The hearing organs of crickets, ants and termites are located on the front legs. Organs which are believed to be for hearing have been discovered at the base of the wings of a wasp and in all the legs of the honey bee.

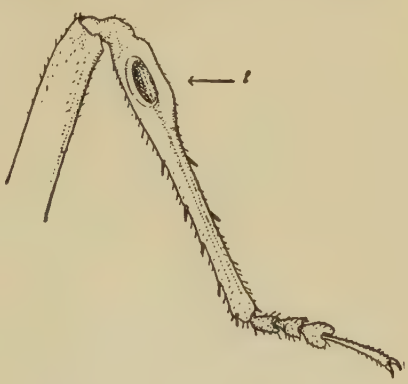


FIG. 8.—Hearing organ on front leg of a katydid. (From Comstock.)

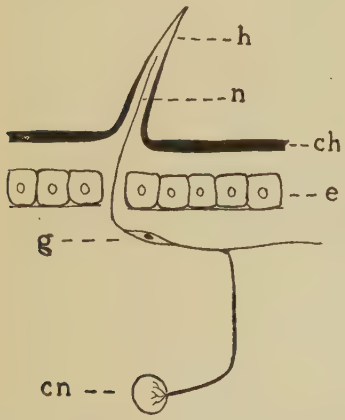


FIG. 9.—Diagram showing nervous connection between tactile hair and central nervous system. *h*, tactile hair; *n*, nerve; *ch*, chitin; *e*, epidermal cells; *g*, ganglion cell of nerve; *cn*, ganglion of central nervous system.

Organs of taste and smell are so similar that it is not always possible to distinguish between them in insects. They both consist of tiny pores or thin-walled hairs which are located in some cavity or other protected place where their surfaces may be covered with enough liquid to form solutions of the particles to be smelled or tasted. The olfactory pores have been discovered by McIndoo on various parts of different insects and some of the pores seem to be widely scattered over the body, but the organs

of smell, as we humans understand smell, are chiefly concentrated on the antennæ, and the sense of taste is probably confined to the mouthparts.

Sensation, of course, is dependent upon more than sense organs. It depends upon nerves to carry the stimuli inside the body to the coördinating centers. Every tactile hair, every olfactory pore, every taste pore, every organ of hearing, every eye lens is connected with the end of a nerve which extends inward.

10. Coördination

Insects have a *central nervous system* consisting of a brain and a chain of ganglia which is comparable to our spinal cord. The central nerve chain differs from the spinal cord, however, in being located along the opposite (ventral) side of the body and in being, of course, much

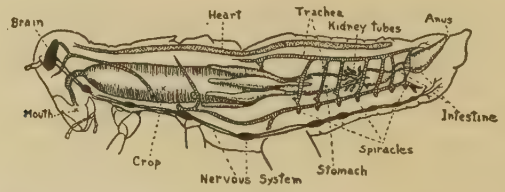


Fig. 10.—Diagram showing relative positions of central nervous system and other systems of a grasshopper.

simpler. There are, extending from the various ganglia of the central nerve chain, nerves which send branches to organs, muscles and sense organs throughout the body. The brain is connected directly with the eyes, antennæ and central nerve chain. The brain receives sensory stimuli directly from the most important sense organs, and converts these stimuli into motor stimuli which are sent to the appropriate muscles. If the brain is removed

from an insect, it can walk or fly, but its course is irregular and aimless, like that of a drunken man. The ganglia of the central nerve chain receive tactile stimuli and convert them into motor stimuli so that legs or wings may be set to work automatically. The seat of coördination, the governor of the activities of the body, is the brain.

There is a system of small ganglia and nerves connecting the muscles of the pharynx, the midintestine, the heart and spiracles with the brain. This is known as the *sympathetic nervous system* and it is believed that emotions of the brain automatically affect the processes of digestion, heart action and breathing.

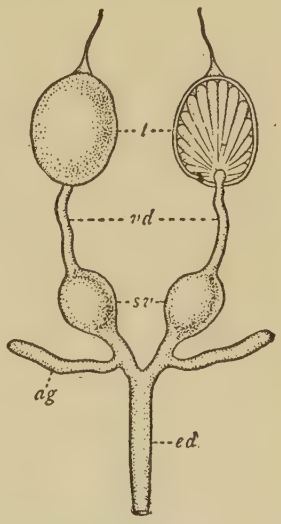


FIG. 11.—Diagram of reproductive system of a male insect; the right testis is shown in section. *t*, testes; *vd*, sperm ducts; *sv*, seminal vesicles and *ag*, accessory glands, secrete accessory fluids; *ed*, sperm duct to exterior. (From Comstock.)

11. REPRODUCTION

Among insects there are two distinct sexes, male and female. In the abdomen of the male there is a pair of reproductive organs, the *testes*, in which *spermatozoa* are formed by repeated divisions of the original germ cells with which that insect was provided before birth. In addition to the primary reproductive organs, the testes, a male insect has glands for secreting accessory fluids which accompany the spermatozoans, and ducts carrying them to the exterior, near the rear end, of the abdomen. Male insects are

usually smaller than females of the same species, and there are sexual differences in form or color in some species.

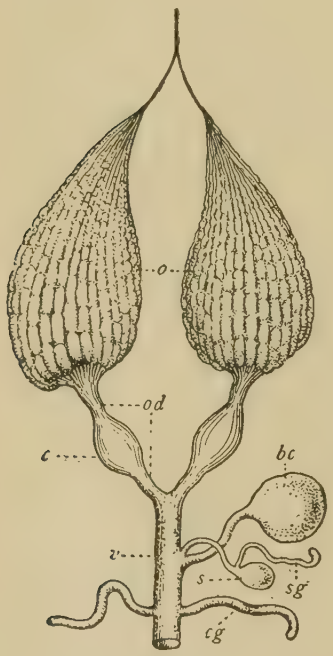


FIG. 12.—Diagram of reproductive system of a female insect. *o*, ovaries; *od*, oviduct; *c*, pouch for storing eggs; *v*, vagina; *s*, spermatheca; *sg*, gland supplying food to sperms in spermatheca; *bc*, bursa copulatrix; *cg*, cement glands. (From Comstock.)

In the abdomen of the female insect there is a pair of *ovaries* in which *eggs* are formed by repeated divisions of the original germ cells. Connected with the ovaries are glands which form a secretion for cementing eggs to each other, or to leaves, twigs and other objects. In some species the secretions form capsules within which the eggs are protected. After an egg has been completed in the ovary, it passes into the oviduct. The oviducts from both ovaries unite to form a single duct called the vagina. Eggs pass through the vagina to the rear of the abdomen, where they are expelled from the body. Many female insects have, near the tip of the abdomen, pointed appendages between which the eggs pass out. These appendages are known as *ovipositors*, and are used for boring holes in which to deposit eggs, or for pushing the eggs deep into crevices.

Near the rear end of the vagina are one or two small

sacs (spermatheca and bursa copulatrix) (Fig. 12) in which the spermatozoa from a male are stored and remain alive for long periods. In many insects the pairing of sexes takes place only once and the egg-laying period of the female may extend over a considerable time, so it is necessary that thousands of spermatozoans be stored within her body for fertilization of the eggs to be laid later. At the time an egg is laid spermatozoans pass from the spermatheca into the vagina and one of them enters the micropyle, a tiny hole through the egg shell,

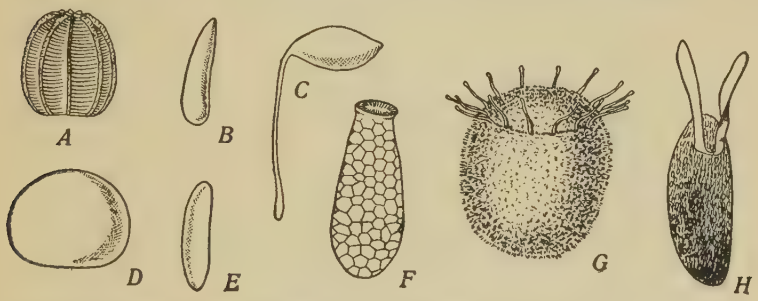


FIG. 13.—Eggs of various insects. *A*, butterfly; *B*, house fly; *C*, chalcid; *D*, butterfly; *E*, midge; *F*, bug; *G*, bug; *H*, pomace fly. From Folsom.)

thus fertilizing the egg. In some ants and bees, which live in large colonies, eggs that are developed in the queens years after the pairing took place are fertilized by spermatozoa which have been stored in the spermatheca all that time.

The eggs of different kinds of insects vary greatly in size, shape and color. Often they are large enough to be quite easily seen by the naked eye and are white, yellow, black, or even banded with black and white. The forms of a few are shown in Fig. 13. Often the shell is marked with small polygonal areas that are the imprints of cells

in the walls of the ovary or oviduct which formed the shell.

Although insects most commonly deposit their eggs on objects outside the body, there are numerous examples of insects in which the eggs develop into young before leaving the mother's body. Flesh flies deposit active maggots on meat. Plant lice deposit colonies of small active plant lice resembling the parent in general appearance. These, and other species which deposit young that have grown beyond the egg stage before leaving the mother's body, are said to be *viviparous* in their reproduction, while the ordinary egg-laying insects are distinguished by the term *oviparous*.

There are some kinds of insects which grow normally from eggs which have not been fertilized by spermatozoa. In fact, some plant lice may continue producing young for many generations without a single male appearing among them. Honey bee queens produce drones from unfertilized eggs and workers from fertilized eggs. The production of young from unfertilized eggs is called *parthenogenesis*. In a few cases it has been discovered that even young insects, such as the maggots of a gnat, *Miastor,* sometimes reproduce young like themselves. This phenomenon of parthenogenesis by young, incompletely developed insects is called *pædogenesis*. Several species of insects have been discovered which go even farther than pædogenesis in their precocity of reproduction. They are tiny parasitic wasps whose grubs live within the body of a caterpillar or other insect. The wasp deposits an egg inside the larger egg of the insect host. As the egg of the host develops into a caterpillar, the egg of the parasitic wasp within begins to develop, and as it grows, it breaks up into a hundred or more individuals, each of

which develops at the expense of the caterpillar and becomes a wasp. Thus we find that even the embryo within the egg may reproduce other embryos by dividing itself; this phenomenon is called *polyembryony.*

The number of young produced by insects varies even more greatly than the ways of producing them. A single queen, among the ants and termites, which build up large colonies, is said to sometimes produce hundreds of thousands of eggs, although she requires years to produce them all. A moth commonly produces a few hundred eggs, all within a week or two. A parasitic fly, commonly called the "sheep tick," produces but one nearly mature "tick" during each of several reproductive periods.

12. Growth

Every insect begins life as an egg, but the ways of growing to maturity are varied. Some, as has been stated above, are expelled from the mother's body as eggs, while at the other extreme are those such as the "sheep tick" which are retained and fed within the mother's body until they are practically mature. In some species, notably ants and bees, the eggs are deposited early but the young are carefully tended and fed prepared food until maturity. In a few species the eggs are dropped promiscuously on the ground with no care as to their future, but most female insects seem to have an instinct for placing the eggs on or near the proper food which the young must eat after hatching. Thus most insects have at least some food provided by the preceding generation for the growth which is to follow the egg stage.

During its growth, from egg to adult, the life of an insect is divided into a series of stages which are separated by brief periods during which eating and locomo-

tion cease while quick growth takes place. During such growth periods there comes normally a shedding or molting of the outgrown chitinous skin and the formation of a new larger one which will allow further growth of the body within. Each stage of the insect is known as an *instar*. Thus, an insect from the time of its hatching out of the egg until its first molt is the first instar of that species; between the first and second molts it is the second instar, etc.

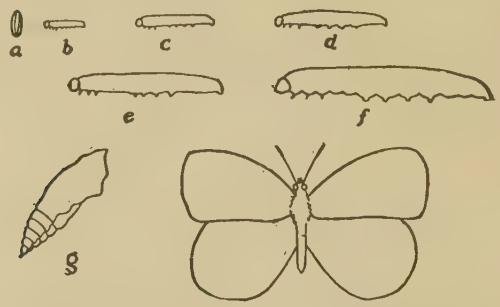


FIG. 14.—Metamorphoses of a cabbage butterfly. *a*, egg; *b*, *c*, *d*, *e*, *f*, larval instars; *g*, pupa or chrysalis; *h*, adult.

All insects change their size and usually some of their proportions during the interval between instars when the old skin is shed, but many insects undergo remarkable transformations at certain of these periods. For example, the common green cabbage caterpillar, at the end of its fifth instar changes its form completely as shown in the accompanying diagram (Fig. 14). Again, at the end of the sixth instar, when the butterfly emerges, there is a great change of form. These major changes in form are known collectively under the term *metamorphosis,* and the various forms of the insect are named as follows: the worm-like form (Figs. 14, b, c, d, e and f) is known

as the *larva;* the transition stage (Fig. 14 g) between larva and adult is known as the *pupa.* Thus there are four distinct forms in which the insect appears during its life, *e.g., egg, larva, pupa* and *adult.* All butterflies, moths, flies, beetles, wasps, and many other insects pass

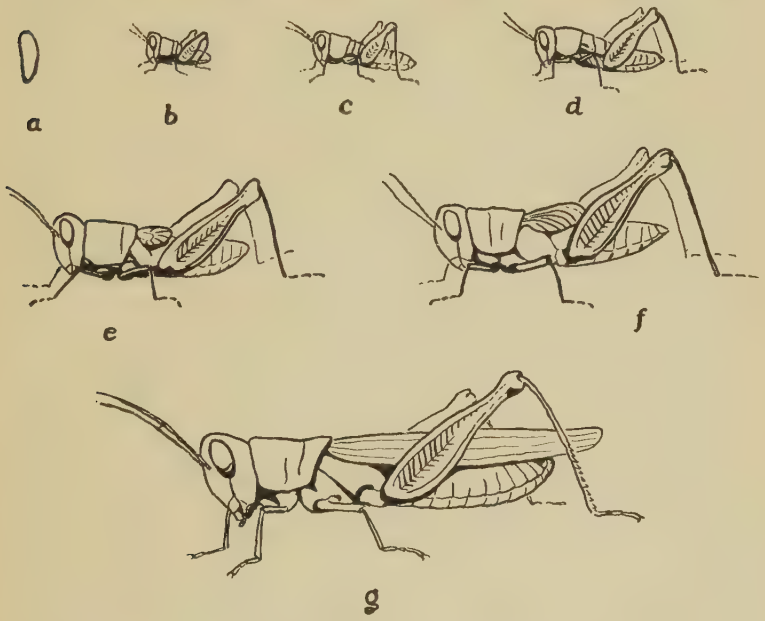


Fig. 15.—Stages in the development of a grasshopper. *a,* egg; *b, c, d, e, f,* the five nymphal instars; *g,* adult.

regularly through these four forms. They are therefore said to have a *complete metamorphosis.* The larvæ of butterflies and moths are commonly called caterpillars and the pupæ of butterflies are often called chrysalids (Fig. 14 g). The larvæ of flies are commonly called maggots, while those of beetles and bees are called grubs.

Some insects, like the grasshopper (Fig. 15), undergo

no remarkable changes in form during their growth but gradually change their proportions at each molt. The most important change they make is the appearance of wings at the beginning of the adult stage. Since the changes in such insects are so incomplete they are said to have a gradual, direct, or *incomplete metamorphosis* and the larvæ of such insects are commonly spoken of as nymphs and naiads. They have no stage corresponding to the pupa of insects with complete metamorphosis.

A few primitive insects, such as *Campodea* (Fig. 27), do not undergo changes in form and never develop wings. They are therefore *without metamorphosis.*

In our temperate regions, where winters bring freezing temperatures and remove most of the green parts of plants, millions of insects disappear along with the leaves. We know, however, that each species lives through somehow from year to year. Some pass the winter only in the egg stage, others as pupæ, while many live through as larvæ and adults. Regardless of the form in which they live through the winter, many insects successfully withstand freezing temperatures for long periods. The insect is not a warm-blooded animal and the temperature of its body changes with the temperature of the air, soil, water, or whatever surrounds the insect. The eggs are not incubated at any particular temperature and are not injured by chilling as a hen's egg is. However, an insect in any form becomes inactive and does not develop during periods of low temperature; all growth and development must await the return of warmer weather. The passage of the winter in a dormant state is called *hibernation.*

We are just beginning to learn how some insects successfully withstand hard freezing periods. Knight has shown that their success seems to be dependent upon

the elimination of all free water from the organs of the body before freezing temperatures overtake them. After water is eliminated, the protoplasm and other body contents is in the form of a dense colloidal mixture which will not crystallize (freeze) until exceedingly low temperatures are reached. The respiration of cells is almost stopped so that they do not require any circulation of foods or removal of wastes while the body is in this state. As warmer weather returns the cells increase their respiration, using the food they have stored and forming enough water from their metabolism to again start circulation in the body. Repeated thaws and freezes cause the insect to use up its supply of stored food and unless this can be replenished by feeding upon other insects or some available food, the insect dies during hibernation.

The following chapters will introduce the habits of a few species of insects picked from among them to represent the more common and important groups of the half million or more species. It is obviously impossible for us to include a study of all the species here; but knowledge grows by the slow addition of small bits closely related to knowledge nuclei we already possess. It is the hope of the writer that a study of the following chapters will result in the student gaining several nuclei of knowledge to which future bits of knowledge about insects will be attracted as the years pass.

REFERENCES:

COMSTOCK, J. H. *An Introduction to Entomology,* 1924.
FOLSOM, J. W. *Entomology,* 3rd edition, 1922.
SNODGRASS, R. E. *Anatomy and Physiology of the Honeybee,* 1925.
FOREL, A. *The Senses of Insects,* translated by M. Yearsley, 1908.
IMMS, A. D. *General Textbook of Entomology,* 1925.

CHAPTER III

ORDER ORTHOPTERA [1]

(Gr. orthos, straight; pteron, wing)

The members of this order have chewing mouthparts; the front wings overlap on the back when at rest and they are slightly thicker than the hind wings which are folded in plaits like a fan when at rest beneath the front wings. The young resemble the adults.

The order *Orthoptera* includes some of the very destructive and well-known insects, commonly found in our fields and houses. The more familiar representatives are the grasshoppers, crickets, cockroaches and katydids. The walking sticks are not so noticeable because of their slow movement and resemblance to twigs, but they are common in the meadows and in some localities upon the twigs of trees also. The praying mantids are often found on plants, waiting for small insects to come within their grasp, and are considered helpful to man because they devour some injurious insects. The common brown or black crickets live close to the soil and in damp houses. They eat almost anything from dead

Fig. 16.—A cockroach. (From Hegner.)

[1] It is the usual practice in discussions of the orders of insects to follow the sequence given in our list of orders on page 8. Since the insects of the order *Orthoptera* are more generally known than the insects of more primitive groups, it seems logical to begin our discussion with this order, and to consider the more primitive insects later.

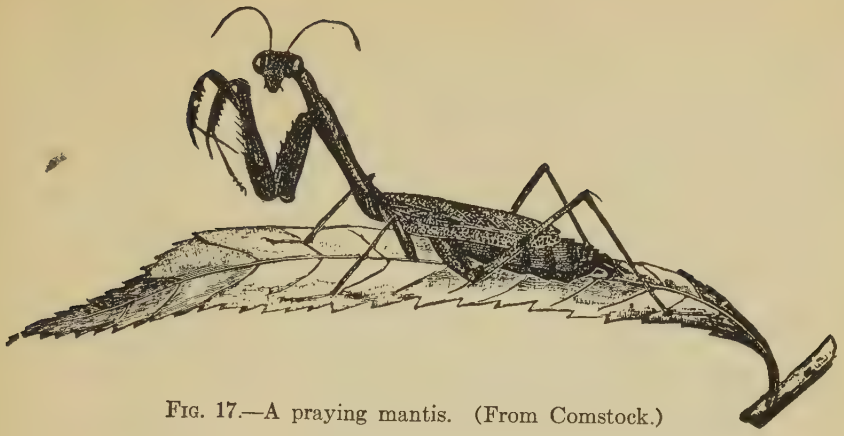


FIG. 17.—A praying mantis. (From Comstock.)

FIG. 18.—A walking stick. (From Comstock.)

crickets to lace curtains but the farmer knows them best as the destroyers of binding twine. The cockroaches live in dark, moist places, such as under the loosened bark of trees or near the waterpipes in our houses. They like the same foods that we like, but they can get along with

FIG. 19.—A katydid. (From Hegner.)

decaying organic matter, such as rotting wood, for food. Katydids are much like grasshoppers but differ from them in usually preferring to perch on woody plants rather than on grasses and herbs of the meadows. The katydids eat the green leaves of plants and the wings of many species resemble the leaves so closely that it requires very careful observation to distinguish the insect from its surroundings. They are best known through the song of the male which seems to some listeners to say "Katy-did! she did! she did!"

FIG. 20.—A cricket. (From Hegner.)

The order *Orthoptera* is a noisy group, for most of the males of crickets, grasshoppers and katydids are musicians. Sometimes they are called "singers" but "fiddlers" is a more appropriate term, for insects do not possess vocal organs. Some of them use the hind leg as a bow and scrape it across a wing-vein which serves for the single

string of its fiddle. Others, as the katydids, use the left wing as a bow to scrape a vein on the right wing. A few grasshoppers make a crackling sound by rubbing the wings together only while flying. Quite a few species of *Orthoptera* have such short wings that they are only useful for "fiddling" and not for flight. Their noise is supposedly for attracting the other sex, a sort of invitation or accompaniment of the dance which is commonly performed at mating time.

Example: **The Red-legged Grasshopper** (*Melanoplus femur-rubrum* DeGeer). Family, *Locustidæ.*

Suppose we catch and examine one of the common red-legged grasshoppers about one inch long which can be found in almost any field in late summer. You can readily see that it has a head which bears a pair of long thread-like feelers or antennæ, a pair of large eyes and a mouth. Next to the head is the thorax, which bears six jointed legs and two pairs of wings. It is at first difficult to see where the thorax ends and the abdomen begins, but if you start just back of the attachment of the hind legs or hind wings, and count the series of similar rings which telescope slightly one into another, you will have counted the segments of the abdomen. If the tip of the abdomen is rounded below, the insect is of the male sex, while if the abdomen has a pointed tip it is a female and the points form an ovipositor which is used for depositing eggs in the ground. The female is also usually longer and larger than the male.

If we look at the head again, using a lens to magnify it, we will see more of the details of its construction. The antennæ are seen to be composed of more than 20 small segments joined end to end. The large eyes look like

miniature honeycombs, each eye being composed of a great many small hexagonal parts. They are, therefore, called the compound eyes. The grasshopper and many other insects as well, have, in addition to the compound ones, three simple eyes, each appearing as a very small, circular, convex lens. There is a simple eye above the base of each antenna and one in the center of the face lower than the antennæ. Below the lowest simple eye

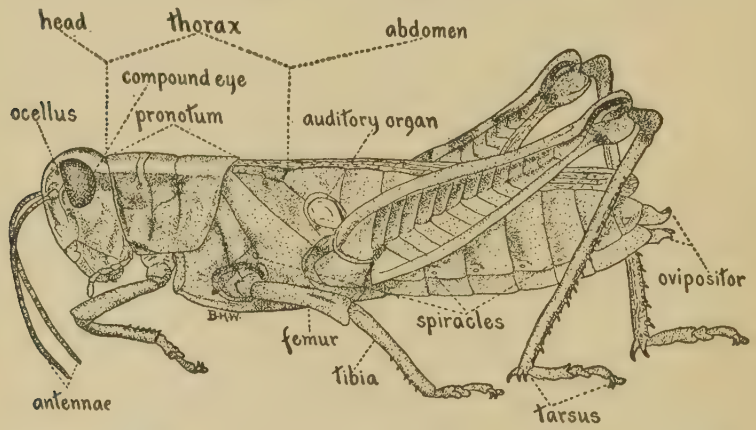


FIG. 21.—Diagram of a female grasshopper with wings of near side removed. (From Walden.)

is a long, straight wrinkle or furrow extending across the face. The part just below this straight furrow is not the insect's lip as the beginner is apt to suppose it to be, but is the clypeus, an immovable part of the face. The upper lip is attached to the lower end of this immovable part. The lip can be raised with a pin. Beneath it will be found two pairs of jaws extending from the sides toward the middle where their tips overlap. The upper, heavier pair of jaws is called the mandibles and the lower more flexible pair is called the maxillæ. Each maxilla bears at

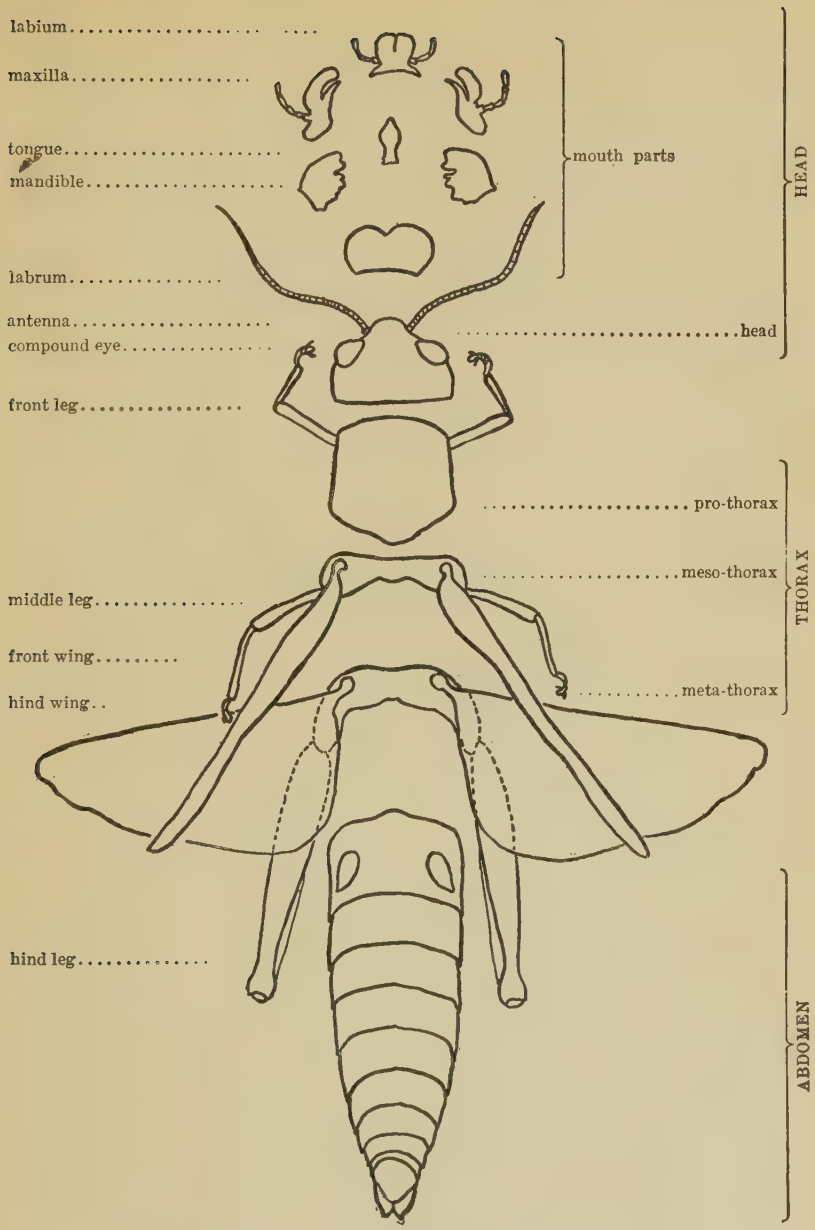


FIG. 22.—Diagram showing parts of a grasshopper.

its outer edge a jointed "feeler" or "taster" called a palpus. The lower side of the mouth is covered by the lower lip which bears a pair of short palpi. On the tips of these palpi are taste buds comparable to those within our mouths. The grasshopper has an advantage over us in being able to taste its food before taking a bite. If you watch one eat a clover-leaf, you may also be surprised to find its jaws working sidewise when it chews instead of up and down like ours.

The fore-part of the thorax fits closely to the rear of the head and is shaped like a saddle above, while below the saddle are the front legs. This fore-part of the thorax is called the pro-thorax. The next part, which bears the middle pair of legs and front pair of wings, is called the meso-thorax and the hind part of the thorax, which bears the long jumping legs and the hind wings, is called the meta-thorax.

The legs of all insects are jointed and composed of a number of segments. There are two quite short segments at the base called coxa and trochanter, then two long segments called femur and tibia, which correspond to our femur and tibia. To the outer end of the tibia is joined the foot or tarsus, which is composed of from one to five parts (three in the grasshopper) and which bears at its tip a pair of claws and a rounded pad called a pulvillus.

Spread apart the grasshopper's wings and you find that the fore or upper wing is long and narrow, while the hind or lower wing is broad and rests, folded like a fan, beneath the upper wing. Feel the texture of the wings and you will find the lower wing thinner and more delicate than the upper one which covers and protects the lower when not in flight.

An insect which possesses wings has reached the adult stage and will grow no larger. Its principal business then is to find a mate and start a family of young which will continue the species. Our grasshoppers may be observed courting prospective mates any time during the summer from June until frost. A few weeks after mating the females are ready to begin depositing eggs.

FIG. 23.—Grasshopper laying eggs. (From Walton, U.S.D.A.)

In depositing her eggs, the female grasshopper chooses a spot of bare, dry ground where the soil is packed solidly. This may be in a meadow or unused path or elsewhere. She digs a hole by means of two pairs of pointed, horny ovipositors which can be spread apart or closed at the tip of her abdomen. With the ovipositors closed, she pushes the tips into the ground and by a continued stretching and contracting of the abdomen as well as a spreading and closing of the ovipositors she drills a hole until nearly the whole abdomen is buried. Then with feet set firmly on the ground she begins to fill the hole with eggs. She takes great pains to place them side by side and in four rows, each row containing about seven

eggs, so arranged that if the young should hatch first from the lower eggs they will not be blocked by the upper eggs from escape to the surface of the ground. Along with each egg she ejects a copious supply of a sticky fluid which agglutinates the eggs into a mass and forms a thin waterproof coating around each egg. When the last egg is laid, the mother fills up the top of the hole with more of the fluid and bits of earth until it is scarcely distinguishable from the surrounding surface. After mating again with the same or another male a few weeks later she is ready to lay another mass of eggs just like the first one. Usually the two masses are all she will produce, but occasionally an individual will produce three or even four masses of eggs. Soon after the eggs are all laid the females, and males also, become sluggish and die. The last ones are killed by frosts in the autumn. The eggs, resting securely in the ground protected from the weather by their waterproof covering, usually remain through the winter. Within the egg the single cell, which has united with the sperm cell from the male, gradually becomes a many-celled young grasshopper. It is believed that the warmth and moisture which promote the development of the embryo grasshopper within also slowly decompose the glutinous covering of the egg so that when ready to hatch, the young hopper, by pushing with its head, can easily break out from its prison. The process

FIG. 24.—Eggs of grasshopper in position in soil. (From Walton, U.S.D.A.)

is similar to the germination of a hard-covered seed in moist, warm soil.

The eggs usually hatch after freezing weather is past in April and May. After hatching, the young of an egg mass escape one after another from the mass through one small hole and rest limply on the ground for a few hours until they become hardened. Then they begin to feed on the nearest vegetation, eating ravenously the green leaves whenever the weather is warm and sunny. During cold, cloudy or rainy days and at night the young hoppers huddle together under the shelter of weeds, fallen grass or other protection, and remain motionless. Possibly they sleep much of this time, but concerning the sleep of grasshoppers or other insects, very little is known.

The young hopper differs but little in appearance from its parent. The most striking differences are the small size, want of wings, disproportionately large head and narrow, weakly developed thorax and abdomen of the young. As the grasshoppers grow the mature winged form is gradually assumed through a series of five molts. With each succeeding molt the rear margins of the meso- and meta-thorax project further backward, overlapping the segments behind and forming pads in which the wings gradually develop on top of the back. The size of the insect, especially of thorax and abdomen, increases with each molt until the mature stage is reached. The time required for growth, from the hatching of the egg to the attainment of wings, is about 75 days. It may be slightly longer if the weather is abnormally unfavorable to growth, or it may be shorter if the weather is abnormally favorable to growth.

During the process of molting or shedding of the skin, our grasshopper quits feeding for a time and remains

stationary. The first three skins are almost invariably shed on or near the ground either while the nymphs are congregated under grass in little hillocks or while clinging to plants they may find for the purpose. The last two molts more often take place above ground, the insects at these stages of growth preferring to fasten to some elevated object.

In order to illustrate the interesting process of molting we will trace an individual through the last molt, as it is,

FIG. 25.—Three stages (*a, b, c*) in the emergence of an adult grasshopper from the last nymphal skin. (From Riley, U.S.D.A.)

on account of the larger size of the animal, most easily watched. The other molts are very similar in mode of execution.

When about to acquire wings, the last-stage nymph crawls up some post, weed, grass stem or other object, and hanging with head downward it clutches the support with the hind feet which are drawn up under the body. Remaining motionless in this position for several hours, with antennæ drawn down over the face and the whole aspect betokening helplessness, the thorax, especially between the wing pads, is noticed to swell. Pres-

ently the skin over this swollen portion splits along the middle of the head and thorax, starting by a transverse, curved seam between the eyes and ending at the rear of the thorax.

As soon as the skin is split the soft and white thorax and head within swell and gradually extrude more and more through the breach by a series of muscular contortions; the new head slowly emerges from the old skin, which, with its empty eyes, is worked back beneath; and the new antennæ and legs are being drawn from their casings and the future wings from their sheaths. The soft, front legs rapidly stiffen upon being exposed to the air and, holding to its support as well as may be with these, the grasshopper employs whatever muscular force it is capable of to draw out the end of the abdomen and its long, hind legs. After a few more minutes this is accomplished, then with unsteady gait it turns slowly around to clamber up the side of the cast-off skin and to rest. The wings gradually expand while every part of the body hardens and gains strength—the crooked limbs straightening and the wings unfolding and expanding like the petals of some pale flower.

The front wings are at first rolled longitudinally to a point and as they expand and unroll, the hind wings, which are tucked and gathered along the veins at first, curl over them. In ten or fifteen minutes from the time of extrication, the wings are fully expanded and hang down like dampened rags. From this time on the broad hind wings begin to fold up like fans beneath the narrower front ones and in another ten minutes they have assumed the normal attitude of rest. Meanwhile, the pale colors which the newly molted insect possesses have been gradually giving way to the characteristic colors

of the species and these colors are now fresh and bright like those of a new hat just from the band box.

If we now examine the cast-off skin, we shall find every part entire, with the exception of the breach through which the insect emerged; and it would puzzle one who had not witnessed the operation to divine how the now stiff hind shanks of the insect had been extricated from the old skin with its bent knees. They were, in fact, withdrawn through the bent knee-joint, so that during the process the shanks were doubled at every point throughout their length. They were as supple at the time as a wet string and for some time after extrication they show the effects of this severe bending by their curved appearance.

The molting, from the bursting of the old skin to the full adjustment of the wings and straightening of the legs of the new adult insect, occupies less than three-quarters of an hour and sometimes but one-half hour. It takes place most frequently during the warmer part of the morning, and within an hour after the wings are once in position, the parts have become sufficiently dry and stiff to enable the insect to move about with ease. In another hour, with appetite sharpened by the fast, it joins its voracious comrades and tries its new jaws.

The molting period is a very critical one, for during the helplessness that accompanies it, the grasshoppers fall a prey to many enemies which would not molest them at other times.

Not only the outer covering of the body is shed during each molt, but also the linings of most of the digestive tube and of the breathing tubes peel off and are cast out.

The red-legged grasshopper will eat a great many kinds of green plants, among them most of our planted

field crops, such as wheat, clover, oats, rye, timothy, blue-grass, soy-beans and corn. In some years when conditions of the preceding seasons have been favorable to grasshopper growth, they may become so numerous that it takes the whole crop to feed them. Nearly every year they eat a considerable portion of the crops and consequently they are recognized as pests of real importance by the food producers. The red-legged grasshopper does not travel far from the field of its birth. It does not seem to have the habit of flying in swarms of its kind from field to field like some of its close relatives do.

References:

Riley, C. V., Packard, A. S., Thomas, Cyrus. 1st Ann. Rept. U. S. Ent. Comm., 1877.

The **Family Locustidæ,** to which the red-legged grasshopper belongs, contains many kinds of large, medium and small sized grasshoppers or "locusts," as they were formerly called. The locust plagues of the Pharaohs were caused by members of this group, and the grasshopper plagues of our pioneer days in the Mississippi valley were the result of invasions of one species, *Melanoplus spretus,* from the Rocky Mountains. Many of us have seen or heard of the voracious appetites of various *Melanopli* which, when left without suitable food after the harvest in wheat fields, will gnaw the shirt on a man's back, the pitchfork handle and many other articles not in the usual diet. The most of the grasshoppers have life histories and habits similar to those of the red-legged grasshopper, but occasionally a drought in uncultivated regions drives some species to move in countless swarms to neighboring

fields or even to other states in search of succulent green food.

The **cricket family** contains another large group of *Orthoptera* and within the group a great variety of habits and appearance is found. There are tree crickets, field crickets and mole crickets. The last named group is composed of species which burrow in the soil, forming a tunnel like that of a mole, but smaller. Their front legs are broad and flat and developed much like a mole's front legs for digging. The mole crickets' eggs are laid in underground chambers and the whole life is probably spent in tunnels under the surface of the soil. For food they eat the roots of plants and insects.

Field crickets are our common black or brown crickets found very commonly under stones or other objects on the ground. They avoid sunshine and become active usually at night or when the light is dim. They eat many kinds of organic food but use most commonly plants and other insects. The eggs are deposited in the ground and the field crickets are always ground-loving creatures.

Tree crickets prefer to live among the leaves on trees, shrubs or tall herbs and the usual color of their bodies is pale green or white, a color more fitting for such surroundings than the dark colors of the ground-loving crickets would be. Male tree crickets produce a whistling sound which is one of the most pleasant forms of all insect music, but the sound is produced by "fiddling" or drawing the right forewing across the left one and not by vocal organs. The most remarkable thing about their music is that all the males of some species in any locality fiddle in unison. While they are tuning up early in the evening it takes some time before they get into unison,

but later in the night after one has stopped to rest he begins his notes again in time with the chorus. Tree crickets nibble bits of leaves, flowers, fruits, fungi, other insects, such as small caterpillars, and the eggs are deposited within the stems of various plants.

Some members of the **katydid family** are much like grasshoppers and have similar habits, but the katydids are usually hidden by their broad green wings which resemble in form and color the leaves of trees and shrubs. An interesting test of the keenness of your observation is to locate a katydid after you have heard it chirping among the leaves. Their eggs are often laid in a neat row attached to a leaf or twig, each egg overlapping the one before. A few members of this family resemble crickets and live in dark places, such as caves, cellars and under stones.

The oddly formed insects known as **walking-sticks** are interesting primarily because of their shape. They feed upon the leaves of grasses and of trees, like many other *Orthoptera* feed, but the walking-sticks move very slowly and often remain quiet for a long time in one place, depending upon their resemblance to twigs and stems to protect them from birds and other enemies. Our common species are all wingless, with long, twig-like bodies and legs. The eggs are scattered on the ground beneath the plants on which the insects are feeding at egg laying time.

The family of insects called the **praying mantids** is not well known in the northern states where these insects are uncommon but they are well known in the southern states and in tropical countries. The common name comes from the name of the family *Mantidæ* and the attitude of waiting with the front legs uplifted like hands

in prayer (Fig. 17). The attitude of the mantid is deceiving us, however, if we think of it as prayerful, for that pose is assumed in the hope of capturing some smaller insect as it comes within reach of the sharp-spined front legs. Mantids must have insects as their chief food and will often dispose of dozens of insects in a day.

The **cockroaches** form another family of the *Orthoptera*. The majority of species of cockroaches live in forests and fields under loose bark, in logs, under stones or other rubbish. We are more familiar, however, with the few species which have become the followers of man and sometimes multiply, under the protection of our warm houses, so as to become loathesome pests. They are general feeders upon our provisions and may also eat book bindings or other articles which contain glue. The cockroaches which inhabit our houses thrive best in warm, moist places such as kitchens, cellars, laundries or near water pipes, where they hide in crevices and avoid sunlight or other bright light. At night they run about in search of food. The eggs are enclosed in bean-shaped capsules which are dropped by the females in their hiding places.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology*, Chap. VIII, 1924.
IMMS, A. D. *General Textbook of Entomology*, pp. 220-237, 1925.
LEFROY, H. M. *Manual of Entomology*, pp. 39-80, 1923.

CHAPTER IV

ORDER THYSANURA

The members of this order are tiny, slender, soft-bodied, wingless insects with a pair of long antennæ in front and a pair of similar tails behind. The compound eyes are lacking and often the simple eyes also. The form of the body does not change with growth.

THE order *Thysanura* contains some of the most primitive insects, which have succeeded in holding their places in life probably mainly because of their retiring dispositions. You will rarely see one of them unless you suddenly remove the cover under which it hides and then it hurries to gain a new hiding place. If you are swift enough to catch one, the chances are it will be badly damaged by the touch, for they are very fragile creatures. Most of the thysanurans live on or near the surface of moist ground, hiding under moss or decayed plants, or under loose soil. Very little is known concerning their habits but it is believed that many species feed on the products of decay, helping the final reduction of the particles back to dust again. Others are probably predaceous. The species (Fig. 26) which we house-dwellers see more often than others is quite excep-

FIG. 26.—Fish-moth. (From Kellogg.)

tional in its habits. It is clothed in shining silvery scales like those of a fish and is quite incorrectly known as the silver-fish or fish-moth. It lives in warm houses and feeds upon starch or glue in book bindings, or loosens wall paper by eating out the paste. It seems best here to study a more typical, although less known, species than the fish-moth.

Example: **Campodea staphylinus** Westw. Family, *Campodeidæ.*

Campodea staphylinus Westw. This insect is believed to be one of the most primitive living insects. It is not well known even to entomologists because of its retiring habits, yet it is possibly one of the most common insects over a large part of the earth. Individuals of this species are numerous in gardens and fields where loose, humid soil occurs and they abound in damp, decaying wood in forests. They have been found in many continents and from mountain top to sea level. In North America they are present in New York, Iowa, California, and probably in most of the states. David Sharp states that he has found then in mid-summer near the shores of the Mediterranean in company with sub-tropical white ants and within a day or two of that time he noticed

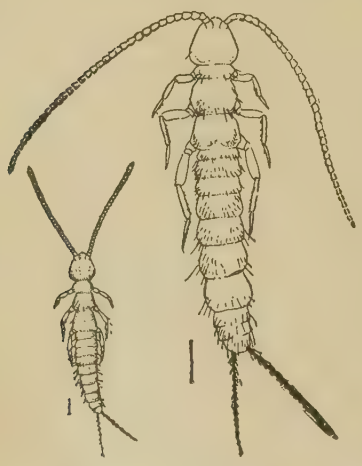


FIG. 27.—Young and adult of *Campodea staphylinus.* (From Kellogg.)

them to be abundant on the actual summit of one of the higher peaks of the Pyrenees, where the conditions were almost arctic and they were nearly the only insects to be found.

Campodea staphylinus has a small, white, elongate, flattened body about one-eighth inch long, a pair of long, many jointed antennæ and a similar pair of tails. The legs are fairly long and slender, the body is very flexible and can be bent freely from side to side like that of a worm. It has no eyes and shuns the light, disappearing very quickly in the earth after it has been exposed. If placed in a container such as a glass tube for observation, it usually dies very soon and is so delicate that it can be safely picked up only with the aid of a small camel's hair brush dipped in alcohol or other liquid which will cause it to adhere to the brush.

The young campodean looks just like its parent except in the size, and it makes no changes in form at any time after leaving the egg. It molts the same as other insects, but may continue to molt after reaching the mature stage. About the only distinction of the adult life is its ability to reproduce its kind. Young and old alike live in moist, loose soil where plants have reached the final stages of disintegration and have become what is known as humus. Their food is unknown but the jaws are curved, toothed and pointed forward like those of predaceous insects. This structure suggests that they may capture and eat other small animals.

References:

Sharp, D. *Cambridge Nat. Hist.*, Vol. 5, p. 182, 1895.
Kellogg, V. L. *Amer. Insects*, p. 60, 1908.
Lefroy, H. M. *Manual of Entomology*, pp. 6-13, 1923.

CHAPTER V

ORDER COLLEMBOLA

The members of this order are tiny, wingless insects, usually with a pair of appendages beneath the tip of the abdomen, which are used as a springing apparatus. The mouthparts are for chewing, but are almost hidden beneath the cheeks. The form of the body is alike in young and old.

Collembola are commonly called spring-tails because of their ability to leap by means of the springing appendages beneath the abdomen. Other leaping insects propel themselves by means of their legs. Spring-tails are very small, sometimes microscopic and rarely more than one-eighth inch long. Many of the species are to be found only in moist, decaying organic matter, and they usually are located among dead leaves and wood, under stones, in moss, in rich, damp soil, etc. Some species are often abundant in winter on the surface of snow, where they may be distinguished as tiny black specks which spring out of our way. These are usually called "snow-fleas" and are often annoying pests of maple-sugar makers because of the habit of leaping into sap buckets. Other species collect on the surface of still water, where they leap about on the surface film.

The food of spring-tails is supposed to consist of decaying or soft vegetable matter, but the food habits of many species are not known. One species, the so-called "garden flea," is often found eating tiny holes in leaves and buds of tender young garden plants. The "garden

fleas" possess a pair of tracheæ which make it possible for the insects to live in drier places than can other *Collembola,* for none of the other groups of spring-tails have tracheæ. Their respiration takes place through the general surface of the body and this surface must, therefore, be kept moist.

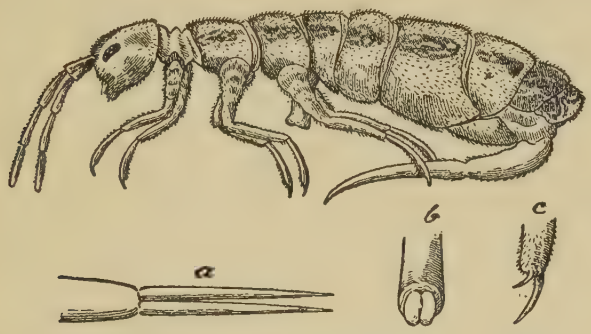


FIG. 28.—Collembolan. *a,* the forked appendage or spring; *b,* the collophore; *c,* claws at end of leg. (From Miall.)

One of the most characteristic features of spring-tails is the *collophore,* from which the name *Collembola* is derived. It consists of a tube, or pair of tubes, extending down from the basal segment of the abdomen and at the tip of each tube is a small membrane which can be pushed out or drawn in. The surface of the sac when pushed out is sticky and supposedly enables the insect to stick to smooth, slippery surfaces. The uses of the collophore have not been conclusively determined.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology,* Chap. VII, 1924.
LEFROY, H. M. *Manual of Entomology,* pp. 14-20, 1923.
IMMS, A. D. *General Textbook of Entomology,* pp. 214-219, 1925.

CHAPTER VI

ORDER EPHEMERIDA

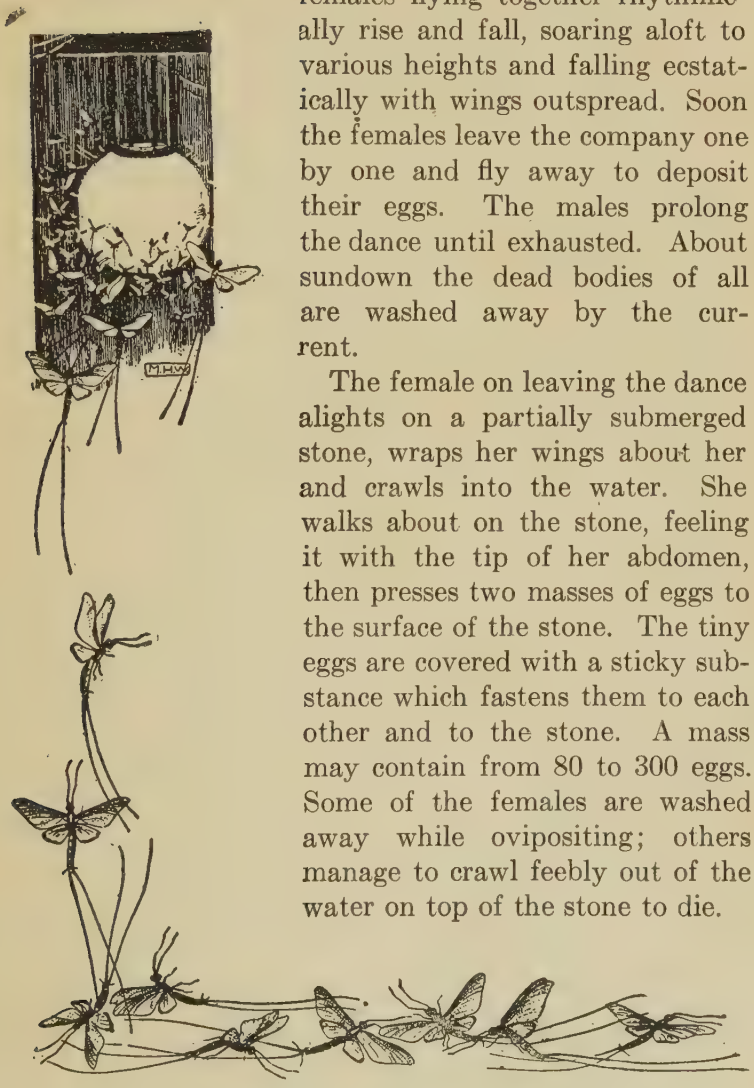
(Gr. ephemeros, lasting but a day)

The members of this order have delicate, transparent wings with a fine network of veins; the fore wings are large and triangular, while the hind wings are very small; a pair of long, slender tails extends back from the tip of the abdomen.

The May-flies, lake-flies or shad-flies, as they are commonly called, are fragile insects, often seen in late spring or early summer by the inhabitants of river or lake towns where thousands of the insects leave the water together and darken the street lights as they dance around them. Their bodies are so transparent that the heart can be seen pulsating within them. Often the sides of buildings near the water may be plastered with hundreds of them or they may cling to the clothing of lakeside promenaders. The entire growth period of the May-flies is spent at the bottom of streams, ponds and lakes. The young, which are sometimes called naiads, are a very important source of food for our edible fresh water fishes.

Example: **Bætis posticatus.** Family, *Ephemeridæ*

During the late afternoon of a day early in May, one may see the mating dance of companies of small, delicate, winged May-flies over the water of a swift stream in numbers varying from hundreds to a pair; males and



females flying together rhythmically rise and fall, soaring aloft to various heights and falling ecstatically with wings outspread. Soon the females leave the company one by one and fly away to deposit their eggs. The males prolong the dance until exhausted. About sundown the dead bodies of all are washed away by the current.

The female on leaving the dance alights on a partially submerged stone, wraps her wings about her and crawls into the water. She walks about on the stone, feeling it with the tip of her abdomen, then presses two masses of eggs to the surface of the stone. The tiny eggs are covered with a sticky substance which fastens them to each other and to the stone. A mass may contain from 80 to 300 eggs. Some of the females are washed away while ovipositing; others manage to crawl feebly out of the water on top of the stone to die.

FIG. 29.—May-flies about an electric lamp. (From Kellogg.)

The eggs hatch in about a month after they are laid. The young *Bætis* larvæ, called nymphs or naiads, swim actively about in the stream and begin eating diatoms almost immediately after hatching. Later they feed on green algæ and gradually add decaying tissues of higher plants to their diet in increasing quantities. They are always vegetarians. As it grows in size, the young *Bætis* molts its skin 27 times before it is full size. The time required for its growth from the time the egg is laid until it reaches the adult stage, is either 6 or 9 months. If the egg is laid in May so that the growth takes place through the summer months, the adult stage is reached by October. The adults of October lay eggs which will produce adults the next August. These lay eggs which produce adults the next May. So it takes just two years to complete 3 generations of the species.

FIG. 30. Young *Baetis posticatus*. (From Murphy.)

At the end of its growth period the naiad is ready to transform and to leave the water. It swims to the surface and strong pulsations in the thorax cause the skin to split along the back. Through this slit there emerges instantly a remarkable winged creature which leaves the water and flutters through the air to a twig or other support, where it rests. There it sits with wings uplifted and forelegs thrust stiffly forward, quietly awaiting another molt, which is to take place in 18 to 24 hours. After this molt the creature has reached maturity. It joins an assemblage of individuals of its species to dance for a few hours, to find a mate and to die. The adult life lasts about as many hours as there are months in the growth period of the naiad. The latter possesses well

developed jaws for chewing but after the last molt the jaws degenerate and no food can be taken by the adult.

The breathing organs of May-fly naiads are interesting as special adaptations for taking in oxygen and giving off carbon dioxide while the naiad remains below the surface of the water. Since most insects are, like man, terrestrial in habit, they are not able to breathe under water. The May-fly naiad, however, has many thin-walled, leaf-like sacs, called *tracheal gills,* which have grown out from the sides of the abdomen, and into each of these gills there extends a branch of the tracheal system of the body. This branch divides into many fine branchlets which extend to all parts of the gill.

While the surface of the gills is wet, the carbon dioxide collected from the body into the trachea diffuses out through the walls of the tracheal branchlets and of the gills into the water. At the same time oxygen, which is held dissolved in the water of the stream, diffuses into the trachea to take the place of the carbon dioxide. If a naiad be watched in a dish of water, the gills will be seen to vibrate, thus setting up currents and bringing fresh, aerated water to bathe the gills.

References:

Murphy, Helen. Lloyd Library, Bul. 22., 1922.
Needham, J. G. N. Y. State Mus. Bul. 47, 1901.
Comstock, J. H. *Introduction to Entomology,* Chap. XII, 1924.
Imms, A. D. *General Textbook of Entomology,* pp. 301-307, 1925.

CHAPTER VII

ORDER ODONATA

(Gr. odous, a tooth or tusk)

The members of this order have a long slender body (tusk-like) and the two pairs of long net-like wings are almost alike in size and venation; each wing has, near the center of the front margin, a node or joint in the vein. The mouthparts are for chewing and the legs are crowded toward the front of the thorax; the antennæ are very small.

The members of the *Odonata* are divided into two groups, known as dragon-flies and damsel-flies. Although both groups, alike, possess the characters given above, there are other characters by which one group can be easily distinguished from the other. Dragon-flies are powerful, tireless fliers, and when they do finally alight on some twig or other perch, the wings rest stretched out away from the abdomen. The head is compact and the eyes close together. Damsel-flies are slender, feeble fliers and rest much of the time hanging from upright sticks or weeds near bodies of water. When not in flight their wings rest folded together above or parallel to the abdomen. The large eyes are set far apart.

Fig. 31. Damsel-fly.

The members of both groups are often beautifully colored and as they fly we may get glimpses of blue, green, violet, or red. Damsel-flies stay near the surface of the water while dragon-flies often fly higher in the air and sometimes venture miles away from

water. While in flight they all capture small insects from the air for food. The eggs of *Odonata* are laid in the water or in objects adjoining the water and the naiads are aquatic. They have well developed thoracic legs but no prolegs. The naiads of damsel-flies have three leaf-like tracheal gills at the tip of the abdomen while naiads of dragon-flies have no abdominal appendages. They usually lie in the mud or trash at the bottom of the water, or hide among water plants awaiting an opportunity to devour smaller animals which come near them.

FIG. 32.—Naiad of damsel-fly. (From Kellogg.)

Dragon-flies are usually large insects and are noticed by practically everyone who goes near the water. Professor J. G. Needham, one of our best authorities on aquatic insects, writes of them thus entertainingly:

"Dragon-flies? Folks call 'em devil's-darnin'-needles in our parts, and they say they will sew up your ears. Yes; and in some localities they are called 'snake-doctors', and are said to bring dead snakes to life; and other meaningless names are given them, such as 'snake-feeders', 'horse-stingers', 'mule-killers', etc.; but in spite of all these silly names and the silly superstitions they represent, dragon-flies are entirely harmless to man—are indeed to be counted as friends, for they destroy vast numbers of mosquitoes and gnats and pestiferous little flies. To such creatures they must seem real dragons of the air. While one is standing by the pond let him follow

awhile the actions of a dragon-fly that is making short dashes in different directions close to the bank. Let him fix his eye on a little fly hovering in the air, and note that after the dragon-fly has made a dart toward

FIG. 33.—Stages of a dragon-fly. (After Brehm.)

it, it is gone. Let him repeat the observation as the dragon-fly goes darting hither and thither. It will be hard to see the flies captured, so quickly it is done, but one can see that 'the place that once knew them knows them no more.' And the usefulness of the dragon-fly in taking off such water-haunting pests will be appreciated."

Example: **Anax Junius** Drury. Family, *Æschnidæ*.

This king of the dragon-flies is a familiar object near water-courses all the way from Alaska to Panama and Cuba. It is found also in Hawaii and along the coast of Siberia and China. *Anax* can be recognized by its large size (body three inches long and wing expanse four

inches), its bright green head and thorax, the head bearing on the upper front a conspicuous spot composed of a blue ring surrounding a yellow ring with a black center, and its clear or sometimes slightly amber-tinted wings. It is one of the first dragon-flies abroad in early spring and members of this species are found on the wing from late March until mid-October in the latitude of central Ohio; they are found in greatest abundance, however, during May and August, soon after emerging from the water.

Flying singly, or sometimes in swarms of twenty or more, they wage a ceaseless warfare on mosquitoes, gnats and other flying insects. Their tireless energy keeps them at it from early morning until dark with but an occasional pause of a moment to alight upon some twig or weed. Needham has seen a swarm of them flying miles from their home (a stream) even on days of high wind when most other insects hunt shelter. Their speed on the wing equals and their agility exceeds that of the swallows. They always capture their prey in flight and are dependent on their wings for getting a living. *Anax* often flies high over the streams following their courses on more or less regular beats. Its legs are not used for walking, but only for perching and capturing prey; to facilitate perching on vertical stems they are set far forward under the thorax and are graduated in length, so that the body when at rest is held in a somewhat horizontal position. This facilitates quick starting and stopping. The six slender legs all arising so close together, armed with sharp spines and claws, form a basket in which the prey is caught and held while it is quickly devoured. The mouth is equipped with strong, jagged

jaws well suited for tearing and crushing the captured prey.

The head is large and is more than two-thirds composed of the pair of great, round, compound eyes. Each eye is composed of more than 30,000 lenses, each capable of seeing a small part of any object in the range of vision. There are lenses directed up and down, sidewise and

FIG. 34.—*Anax junius*. (From Kellogg.)

forward; moreover, the head is fastened to the thorax on such a narrow pivot that it can be rotated through 180°. Can you imagine a greater range of vision? The body is long, smooth and slender, offering little resistance to the air in flight. The thorax is a solid box of muscles, while the abdomen is like a long steering-oar. Dr. P. P. Calvert, a great student of dragon-flies, has observed their slender abdomens expanding and contracting alternately more than a hundred times a minute while supplying air to the great wing muscles.

When *Anax* goes flying about over streams and ponds it is usually engaged in one of three things: capturing food, mating or egg-laying. Its prey may be midges, mosquitoes, gnats, larger flies or even smaller *Odonata*. Beutenmüller found that one of the larger dragon-flies would eat as many as forty house-flies in two hours, and Howard found that if the end of its own abdomen is

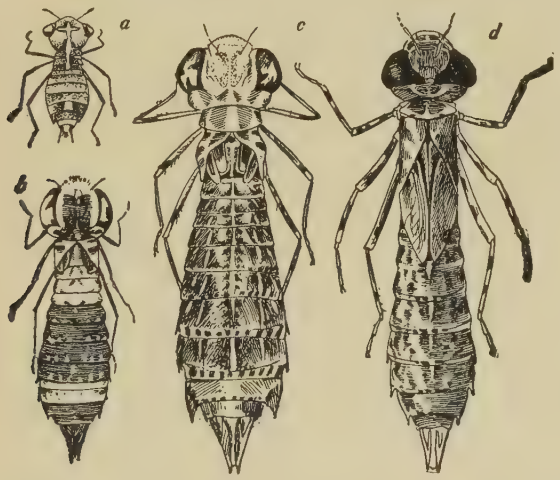


FIG. 35.—Stages in development of *Anax junius*. (From Kellogg.)

bent around to the mouth the dragon-fly will greedily devour the abdomen. Such a voracious creature must indeed destroy thousands of mosquitoes and gnats.

The female deposits her eggs by alighting momentarily on the stem of some cat-tail, reed or other object very close to the surface of the water and inserting a single slender egg into a puncture which she makes with her ovipositors. In early spring the eggs are inserted in the water-soaked stems of reeds, in floating sticks, timbers, etc.; later in the season they are usually inserted in the

tissues of green and growing water plants. Usually plants which extend up through the surface of the water are chosen and the female *Anax* immerses only the tip of her abdomen in the water, but sometimes she descends bodily below the surface to lay an egg in some submerged object.

The naiad is a queer-looking creature with long legs and large head. (Fig. 35.) While very young and about one-tenth of an inch long it is colored with wide bands of brown and white, but later in life it becomes a uniform green or brownish green, and about two inches long. Like its parent it is a strong, active, ferocious dragon among the animal life of its world. It climbs about among the water weeds, with the head poised low and the abdomen slightly elevated, in an attitude of alertness. Its food consists of other water insects, small mollusks, crustaceans, even crayfish and small fish. It is also notoriously cannibalistic. In the midst of abundant and choice food the larger naiads will eat the smaller of their own species, and two of equal size may not safely be kept in close quarters.

The chief organ for capturing prey is the remarkably developed lower lip known as the "mask" (Fig. 36), which is very long, hinged at the middle and folded back under the thorax so that only the broadened tip extends forward to cover the lower part of the face like a mask. The broad tip has a formidable array of hooks and spines for grasping the prey. The lip is extended forward with lightning-like speed and opened by a single

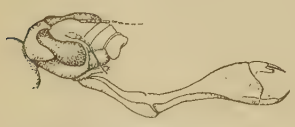


FIG. 36.—Head of *Anax* naiad showing lower lip extended.

movement, and when it closes on its victim it is withdrawn again instantly, dragging the struggling captive back to the jaws, which then become active.

Although entirely aquatic the *Anax* naiad shows no external organs for respiration. This is carried on by means of a respiratory chamber inside the abdomen and made of the modified rear portion of the digestive canal. Through the action of abdominal muscles, the water is alternately drawn into the rectum and expelled again. This is lined with a multitude of tracheal gills which extract oxygen from the water. The naiad, in swimming, propels its body forward by forcefully ejecting water from the respiratory chamber.

After several months of its life in the water the naiad of *Anax,* now fully grown, climbs up some support above the edge of the water, fixes its claws firmly into the support and is ready to transform into an adult. The wings have been growing in pads on its back for more than a month and the other adult organs have been forming internally during this period. The skin of the naiad is split and the adult, after waiting an hour or so for the chitinous covering of its body to harden, is ready to begin its career as the dragon of the air. The transformation usually takes place during the night or early morning, but there are often belated individuals which may be devoured by birds before the chitin has hardened sufficiently for flight.

There are probably two generations of *Anax* each year. Adults may be found laying eggs during any month from March to October and young in all stages may be found throughout the year. Therefore, it seems that there is no regular periodical time when distinct broods

emerge within a short period. Eggs laid in early May produce adults in August and eggs laid in August produce adults the following spring.

References:

Needham, J. G., and Hart, C. A. Ill. State Lab. Nat. Hist. Bul., Vol. XI, pp. 46-50, 1901.

Kellogg, V. L. *American Insects,* pp. 75-98, 1905.

Comstock, J. H. *Introduction to Entomology,* Chap. XIII, 1924.

Imms, A. D. *General Textbook of Entomology,* pp. 308-321, 1925.

CHAPTER VIII

ORDER PLECOPTERA

(Gr. plecos, plaited; pteron, wing)

The adults of this order have two pairs of membranous wings which are usually longer than the body and are coarsely netted with cross-veins. The hind wings are folded lengthwise when at rest on the back and are, when unfolded, wider than the fore wings. The antennæ are long and there are two short tail-like appendages at the tip of the abdomen. The young are aquatic and usually possess tracheal gills.

Plecoptera are commonly called stoneflies; they are usually found near rapid streams and wave-washed rocky shores of lakes, but are not conspicuous insects because of their retiring habits and dull colors. They vary from small to 2½ inches long, and are usually about the color of rocks and twigs on which they rest. When at rest the wings fit closely over the flat abdomen, concealing it from view. A few males are wingless or have short wings. Very few of them are active during the day; the majority are nocturnal and consequently their habits are not well

FIG. 37.—Stonefly. (From Comstock.)

known. It is said that most stoneflies do not feed in the adult stage, but some species have well developed chewing mouthparts and one species is known to injure the buds of fruit trees near the banks of streams. Adult stoneflies may be found every month of the year, even in the northern states. Some small black winter forms may be seen on warm winter days on snow banks, where their color makes them conspicuous; following these come the more common spring forms and during midsummer several greenish, foliage-inhabiting stoneflies appear.

FIG. 38 — Naiad of a stonefly. (From Comstock.)

The females are supposed to drop their eggs in large masses in the water, and several thousand eggs may be deposited by each female. The naiad spends its life under stones or other debris which is continually being washed by fresh water; the riffles in streams and the rocky shores of lakes are ideal places for its development. Some naiads eat dead vegetation which collects about the stones and others prey upon small animal forms; the food and habits of many are unknown. The young of one species completes its growth in one year and passes through 22 instars during its naiadal period. It is believed that some of the larger species require two or even three years to complete their growth.

Plecoptera is one of the smaller orders of insects; there are about two hundred species known in North America and less than five hundred in the world. They are insects of very little importance to man.

REFERENCES:

NEEDHAM, J. G., and CLAASSEN, P. W. *Plecoptera of North America,* T. Say Foundation, Vol. 2, 1925.

WU, C. F. *Morphology, Anatomy and Ethology of Nemoura,* Lloyd Library Bul. 23, 1923.

COMSTOCK, J. H. *Introduction to Entomology,* Chap. XIV, 1924.

IMMS, A. D. *General Textbook of Entomology,* pp. 243-248, 1925.

CHAPTER IX

ORDER EMBIIDINA

(Gr. embios, lively)

The members of this order are small, slender, flat-bodied insects. Some are without wings; others have two pairs of extremely delicate membranous wings, which are very similar in form and rest folded on the back; there are few veins in the wings. The mouthparts are for chewing. The antennæ are fairly long and there is a pair of short tail-like appendages at the tip of the abdomen. The young resemble the adults.

Embiids are found in the warmer regions of the world. A few have been discovered in our southern states. They are very active creatures both in running and in flight.

Fig. 39.—An embiid. (From Folsom after McLachlan.)

Some species live together in flocks and make silken nests under stones or other objects covering the ground. When the surface is too dry they burrow into the ground. Young and old all live together in a nest and the females of some species bestow much care upon the eggs and young. Due to their secretive habits Embiids are seldom seen even where they are abundant. Little is known concerning their food or habits. It is

said that some of them feed upon vegetable matter. The order is a very small one, with only 61 known species in the world.

The metamorphosis of Embiids is peculiar in that the wings develop inside the body instead of in external pads like the wings of other insects whose young resemble the adult.

References:

Melander, A. L. *Biol. Bul.*, Vol. 4, 1902.
Comstock, J. H. *Introduction to Entomology*, Chap. XVII, 1924.

CHAPTER X

ORDER ANOPLURA

(Gr. anoplos, unarmed; oura, tail)

The members of this order are small, wingless insects found upon the skin of mammals or the clothes of man. The head is narrow, while the body is broad and flat. Each foot possesses a single hook-like claw suitable for clinging tightly to hairs. The mouthparts are for sucking the blood of the host. The young resemble adults very closely.

Anoplura are the true lice which occur on man and on other mammals. The best known examples are the body lice of man, often called "cooties," and the lice found on horses, cattle, sheep, hogs and other domestic mammals. There are species of lice occurring on dogs, mice, rabbits, squirrels, elephants and even on the aquatic mammals, such as the seal and walrus. Every species of louse lives only on its own particular species of mammalian host. Although horses and cattle and sheep and men have been in close contact for hundreds of years, they have all retained their distinct species of lice and have not become infested with the kinds of lice belonging to the others. It has also been determined by Vernon L. Kellogg that the species of lice most nearly alike are found on mammals which are nearly alike. For instance, the lice found on monkeys, apes, and men are very nearly alike but are quite distinct from the lice found on other species of mammals.

Since *Anoplura* are blood-suckers they are able to carry

blood diseases in their bodies from one victim to another. It is their ability to be disease transmitters that gives to these insects their greatest economic importance. Under the conditions that usually prevail in crowded camps it has been impossible for soldiers especially to keep themselves free from "cooties" or "seam squirrels" or "graybacks," as the louse of man has been commonly nicknamed. And with the spread of the louse comes the prevalence of certain diseases. Typhus and trench fevers became quite prevalent in the army camps of Europe during the years following 1914 and were only checked by "delousing" operations which checked the spread of the lice. But aside from their importance as disease carriers the *Anoplura* are annoying pests and when numerous they seriously affect the nervous system of the host by the continued irritation of the skin.

Example: **The hog louse** (*Hæmatopinus suis*). Family, *Hæmatopinidæ*.

Hæmatopinus suis Linne. "The hog louse," writes Laura Florence, who has made an intensive study of this insect, "is the largest louse affecting domestic animals and is of common occurrence wherever the hog is found. The hog is its only host and when not molested the parasite is likely to increase in large numbers and cause an unthrifty condition in the herd. (Stockmen handling hogs often become temporary hosts of the louse, but it has never been known to remain for any length of time on the human body, and attempts made to propagate *Hæmatopinus suis* on dogs have met with repeated failure.) On the hog the lice frequent the folds of the skin on the neck and the jowl, the inside and the base of the ears, the inside of the legs, the flanks, and, in

smaller numbers, the back, where they crawl under the scales to get in contact with the new skin."

The hog louse is of a grayish, inconspicuous color. Its body is almost one-fourth inch long when full grown and about one-eighth inch broad across the widest part. The abdomen is flat and broad, while the head is quite narrow, as is shown in Fig. 40. The antennæ arise at the sides of the head and are composed of five very small segments. The three pairs of legs are all of about equal size and are peculiarly fitted for clinging to hairs. Instead of a pair of claws attached rigidly on the end of each leg like most insects possess, the louse has a single movable claw on the end of the leg. This claw can be bent downward to meet a projecting spur on the leg and the hair of the host is pinched between as if by a pair of pincers. The lice climb about over the hairs and appear to walk sidewise as often as forward. Having no sight, they must be guided by other senses, such as touch and smell.

FIG. 40.—The hog louse. (From Florence.)

Projecting out in front of the head is a very short, blunt beak inside of which lies the feeding apparatus. When a louse is about to feed, it moves its head back and forth close to the skin of the host, feeling the surface with the antennæ. Having selected a suitable place it pushes the inner walls of the beak out beyond the end of the outer wall so that some tiny hooks on the inner wall are exposed. These hooks become anchored in the host's skin and hold the louse securely in

place while it feeds. No amount of shaking and twitching of the skin by the host will loosen the insect. After making its position secure, the louse then pushes out from their hiding place two tiny, sharp forks which extend out through the beak between the hooks and prick the skin until the blood flows. While the skin is being pierced the louse raises its abdomen, pushes with its whole body and at the same time the claws make irregular scratching motions which are irritating to the host. Saliva is pumped out of the beak to mix with the blood and prevent its coagulation, then the blood is sucked up into the alimentary canal. Along with the sucking of the blood there starts a continuous peristalsis which passes along the whole alimentary canal and removes from the intestine the debris of the preceding meal. It is the regular habit of the louse to continue feeding until it has emptied the intestine of all fecal matter and has so completely filled the entire canal with fresh blood that a drop of it passes out through the anus. Occasionally lice have been observed to take in so much blood that the stomach bursts and the louse dies. The average length of the meal is about ten minutes, but it sometimes lasts twenty or thirty minutes, and the louse may take three or four meals per day. Temperature influences the amount of food required. Increased temperature increases the metabolism and the food requirement. Taken from its host and confined without food the hog louse is a short-lived insect and dies within 28 to 30 hours of its last feeding. The unfed louse is of a grayish color and much wrinkled while the fed louse has a smooth, shining back.

The eggs of *Hæmatopinus suis* are laid one at a time on the hairs of the hog and are most abundant on the

lower side of the body. The egg-laying process as watched by Miss Florence was as follows: After feeding for about 10 minutes, the female louse withdrew the mouthparts but remained stationary, clinging to a hair with the abdomen curled under so that its end surrounded the hair. While in this position, a tiny, white egg, oval in shape, was attached to the hair by means of a clear cement which accompanied the egg. After a few seconds, the louse moved away, leaving the egg attached firmly to the hair. The louse laid from 1 to 4 eggs in a day and sometimes attached several to the same hair. Nothing is known of the total number of eggs the hog louse may produce, but in related species more than a hundred are produced during the oviposition period which covers about a month. Probably a similar number is produced by this species. A female louse was observed which lived 6 days after oviposition was ended and it is probable that most of the hog lice live about that long, although we cannot be sure of the fact without further experiments.

The eggs are kept warm by the body of the hog, but the length of the egg period varies somewhat with the external temperature. At body temperature, some eggs hatched twelve days after they were laid, while others kept at a slightly lower temperature, such as might be found near the outer end of the hog's hairs, hatched twenty days after. The young louse resembles its parents in shape but is quite small and pale in color. It grows to its final size in 16 to 18 days, remaining the entire time on its host. As one hog rubs against another, the lice may change hosts. During the growth period the louse molts three times. In molting, the skin always breaks in the same line—along the middle of the back from an-

tennæ to sixth segment of abdomen, and at the front end of this line a cross line between the two antennæ. The louse, when ready to shed its skin, sucks in air to fill the alimentary canal and thus inflate the body. The inflation ruptures the old skin and the insect slowly crawls out through the opening, head first. The process takes but a few minutes.

Since the lice live all the time close to the skin of a warm-blooded animal they are able to continue active the whole year and numerous broods are constantly being produced, so that all stages may be found at any time. Because most of the hogs are sent to the packing house each year, most of the lice from the drove are removed with them and this practice tends to keep the number of hog lice much smaller than it would be under natural conditions.

References:

Florence, Laura. Cornell Univ. Agr. Exp. Sta., Memoir 51, 1921.
Comstock, J. H. *Introduction to Entomology,* Chap. XIX, 1924.
Imms, A. D. *General Textbook of Entomology,* pp. 295-300, 1925.

CHAPTER XI

ORDER MALLOPHAGA

(Gr. mallos, wool; phagein, to eat)

The members of this order are small, wingless, louse-like insects, usually with broad head and broad flattened body; found as parasites on skins and feathers of birds and mammals. The mouthparts are for chewing. The young resemble adults.

Mallophaga are usually called bird-lice because they live chiefly upon birds, but there are some species which live upon the skins of mammals instead of birds. They are distinguished from true lice (*Anoplura*) by the mouthparts which are of the chewing type, and in most species the head is much larger than that of true lice. Bird-lice feed upon feathers, hair and bits of dry, scaly cuticle from the skin. They are small, flat insects, usually ranging from one-sixteenth to one-eighth inch in length, and have claws which enable them to cling to the host very securely. Those which infest birds have two claws on each foot and can run about among the feathers, while those infesting mammals have but one claw which is adapted for clinging to hairs so that the insects may not be scratched off easily. The front legs are shorter than the others and are used for carrying food to the mouth.

The eggs of bird-lice are glued singly to hairs or feathers of the host animals. The young live continuously on the host and always resemble the adults except

in size and color; the young are lighter in color and smaller. Growth is completed in a few weeks and since they live upon warm-blooded hosts there is a continuous round of generations throughout the year; however, the winter generations are developed more slowly.

When bird-lice are very abundant, they cause bare areas to appear on the birds where feathers have dropped out as a result of the feeding of the insects. It is to

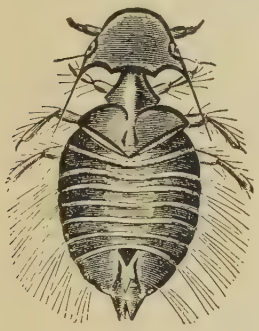


FIG. 41. Turkey louse. (From Comstock, after Law.)

FIG. 42.—Sheep louse. (From Comstock, after Law.)

FIG. 43.—Horse louse. (From Comstock, after Law.)

free themselves of these parasites that birds wallow in dust, and it is for this purpose also that poultrymen dust fowls with sodium fluoride. *Mallophaga* are pests of poultry, cattle, horses and dogs, and many wild animals. About 1,350 species are known to exist in the world and each species is usually restricted to a few closely related host species.

REFERENCES:

KELLOGG, V. L. *Amer. Insects,* pp. 113-122, 1908; Mallophaga, in Genera Insectorum, Fasc. 66, 1908.

IMMS, A. D. *General Textbook of Entomology,* pp. 290-295, 1925.

CHAPTER XII

ORDER CORRODENTIA

(L. corrodens, gnawing)

The members of this order are small, winged or wingless, soft-bodied insects often found on bark or among undisturbed papers in damp rooms. The two pairs of wings, when present, are membranous with a few prominent veins and are not folded but held slanting like a steep roof over the back. The mouthparts are for chewing and the young resemble adults in form.

The winged members of the *Corrodentia* are called psocids because they are of the family, *Psocidæ*. They live upon the bark of trees, on stones, fences, etc., where they eat lichens, fungi, bits of bark and other dead vegetable matter. Sometimes they live together in groups. The eggs are deposited in masses on the bark or wherever the group finds its food, and the female covers each mass with a web of silk. The young live in the same manner as the adults. The young differ from adults principally in the lack of wings, which develop in pads on the back during the latter part of the nymphal period. A few giants of the group found in South America are about one-half inch long, but most of the psocids are less than one-eighth inch in length.

Fig. 44.—A psocid. (From Kellogg.)

The wingless *Corrodentia* are commonly called booklice and are commonly found among old books, papers,

sawdust, etc., about houses. They are grayish or yellowish white with black eyes and are about one-sixteenth inch long. (Fig. 45.) The tiny creatures often occur in large colonies among old papers in damp, shaded rooms, where they breed undisturbed. They are not restricted to a literary diet, but will gnaw wall paper, photographs, glue, etc., as well. The writer has found large numbers of them living in the sawdust packing within the walls of old ice boxes, from which they may be seen to issue and run about while the light is dim.

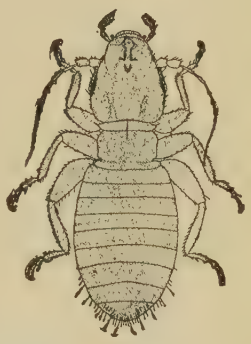


FIG. 45. — Book louse. (From Kellogg.)

Although the book-lice sometimes injure old books, the order as a whole cannot be considered as of any considerable economic importance. There are about 600 species known.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology*, pp. 331-334, 1925.
KELLOGG, V. L. *Amer. Insects*, pp. 111-113, 1908.
LEFROY, H. M. *Manual of Entomology*, pp. 95-98, 1923.

CHAPTER XIII

ORDER THYSANOPTERA

(Gr. thysanos, fringe; pteron, wing)

The members of this order are tiny, slender, wingless or winged insects usually found on plants. The two pairs of wings, when present, are narrow, almost veinless and surrounded by a fringe of long hairs. The mouthparts are for sucking and the young resemble the adults.

THESE tiny insects are known as thrips. They vary in size from one-fiftieth to one-third inch in length and the winged thrips may be easily recognized by their fringed wings. (Fig. 46.) The wings rest flat on the back and are so narrow that they need no folding except bending down the fringe of hairs to get them out of the way for running. The body is elongate and slender enough to run in and out between the petals of a partly opened flower. They are commonly found in the flowers of daisy, clover, apple, pear, etc. Usually thrips are very active and can run, leap or take wing when disturbed. Sometimes when disturbed they turn up the pointed tip of the abdomen as if to sting.

FIG. 46.—Thrips. (From Kellogg.)

The different species of thrips vary in their habits of

feeding; some suck the sap from the tender parts of flowers and other young growth of plants; others feed upon the soft juicy parts of insect eggs and mites. A number, like the onion thrips, wheat thrips and pear thrips, are pests of our cultivated plants and must be destroyed at times to save the crops. Their injury to leaves often shows as grayish-white spots on the surface and their injury to blossoms causes them to blast.

The eggs are placed in various places. Some species lay them under the bark or on the surface of leaves, others insert the eggs into the plant tissues beneath the epidermis of leaves by means of a sharp ovipositor. The eggs of some species which have been observed hatch in from three to fifteen days and the young grow to maturity in from five to forty days. The young resemble adults in form, but are exceptional among such insects in having a quiet, non-feeding instar, the pupa, preceding the adult. There are usually several generations a year and the winter is passed in either larval, pupal, or adult stage. Hibernation takes place under bark, under fallen leaves, in dry, hollow plant stems, etc.

Many species of larger, more slowly moving thrips have been found to destroy eggs and small larvæ of insects and mites. They are, therefore, somewhat beneficial to us.

References:

Hinds, W. E. "Thysanoptera of N. A.," in *U. S. Nat. Mus. Proc.*, Vol. 26, 1902.

Comstock, J. H. *Introduction to Entomology*, Chap. XVIII, 1925.

Imms, A. D. *General Textbook of Entomology*, pp. 322-327, 1925.

CHAPTER XIV

ORDER HEMIPTERA

(Gr. hemi, half; pteron, wing)

The members of this order have a beak for sucking; the basal half of the front wings is thicker than the apical half and the wings overlap on the back when at rest. Antennæ jointed and conspicuous or, in some aquatic species, hidden in grooves under the head. The young resemble adults in general form.

The order *Hemiptera* includes all the forms which may be truly known as "bugs." The bed bug, squash bug, red bug, stink bug and chinch bug are typical bugs. It is a large order, including many families with widely differing habits. Some live on land, some in water and some spend a portion of their time on land, the rest of the time on the water. Some live at the expense of plants by sucking their sap, while others feed upon the blood of animals. They all resemble the adult throughout the nymphal stages and their wings grow in pads on the outside of the back. At the time of the last molt, the two pairs of wings unfold from these pads and come to rest flat on top of the back with their edges overlapping across the rear part of the back.

For examples of this order we will study one member of each of the three groups whose habits are most distinct—the aquatic bugs, the plant-eating bugs and the predaceous bugs. Some authors include the *Hemiptera* and the order *Homoptera* both in one order, called by

several writers the *Rhynchota* and by others the *Hemiptera.*

1. Aquatic bugs

Example: **A water boatman** (*Arctocorixa alternata* Say). Family, *Corixidæ.*

Watch carefully the movement in most any quiet pool which does not dry up very frequently and you may find in the shallow water little brown, oval swimmers three-eighths inch long coming to the surface for an instant,

Fig. 47.—*Arctocorixa alternata,* adult. (From Hungerford.)

then darting to the bottom again to hide among the leaves and other débris which has settled there. They move through the water quite rapidly by means of an excellent pair of oars, the hind legs, and are therefore known as water boatmen.

The boatmen spend most of their time at the bottom of the pool getting food out of the flocculent ooze which

is formed by the disintegration of plants and the growth of minute slime plants and animals. Their bodies are very well adapted for this mode of life. The hind legs are long, flat and bordered with close rows of long hairs which spread out with the pressure of the pulling stroke and collapse on the return stroke, thus making most efficient oars. The middle legs are long, slender and bear two claws on the tip. They are used for grappling the irregularities of the bottom of the pool and the stems of plants, thus holding the bug to its foraging grounds and preventing its floating away. The front legs, however, are quite short, flat and spoon-shaped.

FIG. 48.—*Arctocorixa alternata*, nymph. (From Hungerford.)

The food of corixids is gained by use of the front legs. They sweep up the organic ooze of the bottom with its included plant and animal population and by means of the continued motion of the feet, a stream of the ooze is kept passing over the mouth. The mouth of a water boatman, like the mouths of all members of the order *Hemiptera,* is of the suctorial type. There are no jaws for chewing and usually the insects having suctorial mouths can take only liquids, such as the juices of plants or blood of animals. The mouth of most bugs consists of a long, sharp-pointed beak with saw-like stylets inside, which can be projected from an opening at the tip of the beak. These stylets are used to saw a

FIG. 49.—*Arctocorixa alternata*, egg. (From Hungerford.)

hole through which the juices of the plant or animal victim can flow. The stylets are hollow and fit together so tightly as to form two canals between them. Through one of these canals saliva is forced out into the wound to prepare the juice so that it may be sucked up through the other canal into the stomach. The boatman, however, has a very short, broad beak, which is exceptional in that it has a large mouth opening on the front of it instead of a small one at the tip like other *Hemiptera*. The food canal in the boatman's beak is also relatively large and allows the ingress of small solid particles, such as algæ and diatoms. These are taken from the ooze as it passes over the mouth and are swallowed.

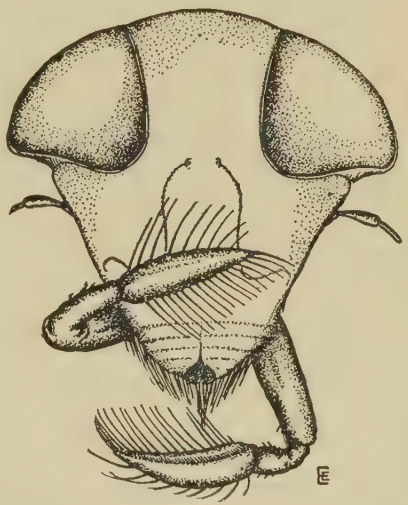


Fig. 50.—*Arctocorixa alternata*, view of face. (From Hungerford.)

Although it lives upon the bottom, a boatman must come to the surface every few hours for air. It breathes air through its spiracles just as a grasshopper does, but an extra air supply of the boatman is carried under its wings between the joints of its thorax, so that by exposing just the thorax above water for an instant the air supply is renewed and the insect can remain below until the supply becomes stale with CO_2. Hagemann found that *Corixa* often remained below the surface one and one-

half hours and could be forced to remain below four to five hours without renewing its air supply.

The water boatman hatches from an egg which has been attached by the mother to some solid object in the water. She may attach it to the stem or leaf of a plant, to a stick, board, stone or even to the shell of a living snail. Another species of corixid usually attaches its eggs to the sides of a crayfish to be carried about until they hatch. The egg of our species, *Arctocorixa alternata,* is very small, measuring about three-tenths of a millimeter long. It is oval in shape and white when laid, but turns yellow as it develops. It will hatch in from one to two weeks. In hatching, the egg shell breaks at the tip and folds back in six or seven points like the petals of a flower unfolding. The nymph pushes its head out through the opening still enclosed in a thin membrane which has covered the animal inside the shell. Soon after its head is out of the shell the nymph shoves so hard that it splits the membrane and wiggles until it is free. Although still soft and white it can swim a few inches to reach some support, then it rests exhausted for some time. It gradually hardens and gains color but begins to feed before the natural color has all appeared. The young nymph seems to have the ability to take oxygen directly through its skin from the water and does not come to the surface to breathe. It continues this method of respiration until after the third molt, when the body seems to be too large and firm to receive sufficient oxygen through the skin, so the bug must rise to the surface and breathe there.

The corixid grows for about 6 weeks and during that period molts 5 times. At the end of the 6 weeks it has become mature, as is evidenced by its possession of two

pairs of full grown wings and by its habits. The nymphal business was almost entirely food getting. The adults spend some time feeding, but they spend much time mating and placing the eggs. Only one egg is laid at a time and the process may cover several weeks before all the eggs are laid. The first eggs laid may hatch and the young grow to maturity before the mother has completed her mission. All the boatmen seem to become mature before winter comes to glaze the pool with ice, and they hibernate in the mud at the bottom. As soon as the ice breaks up in the spring they begin feeding again and mating. As soon as the water warms up in April the egg laying begins, and during the rest of the season individuals of all ages may be seen. There are probably two generations each year, but these overlap so that it is difficult to know what generation an individual belongs to.

The adults can fly in the air and in the spring some fly to other pools, many of which will be dried up in midsummer. Thus the temporary pools may be stocked with boatmen each year, but the young which do not gain wings before the pools dry up will perish and the adults must fly to other water. Their flights and egg laying are performed by night or during cloudy weather, and only the trips to the surface for air may be observed in bright daylight. The corixids can be successfully reared in aquaria in which are placed old leaves which have gathered a coating of slime from the water.

REFERENCE:

HUNGERFORD, H. B. Kans. Univ. Sci. Bul., Vol. XXI, No. 17.

There are many other kinds of water bugs equally interesting to the student of insects. One family, the

Notonectidæ, is known as the "**back swimmers**" because its members swim on their backs. Another family, the *Gerridæ,* is called "**water striders,**" for its members can walk or skate over the water, held up by the surface film. The *Nepidæ* are called "**water-scorpions**" because of their long tails. They can remain below the surface, feeding on smaller insects or small fish and breathe by extending the long tail to the air above. The largest individuals among water bugs are the *Belostomidæ,* or

FIG. 51.—Back swimmer. (After Weed.)

FIG. 52.—Water strider. (From Comstock.)

"**giant water bugs,**" which can destroy fishes up to 3 inches long. They are fiercely predaceous insects and can inflict painful bites with their sharp beaks. Some members of the family are over 2 inches long. In this family we find interesting examples of males who are forced by the females to carry their eggs about on the backs until the eggs hatch. Each female glues a batch of eggs on the back of a male in spite of his vigorous opposition.

There are several families of bugs which live on muddy or sandy shores near the water and often dig holes in which to live part of the time underground. One group is known as the "**shore bugs,**" while another is called "**toad bugs,**" because their short, broad bodies and pro-

truding eyes remind one of a miniature toad in general appearance. They are colored so like the soil on which they rest that it is difficult to distinguish them except

Fig. 53.—Water scorpion. (From Comstock.)

Fig. 54.—Giant water bug. (From Comstock.)

by careful search. They rest quietly, waiting for a chance to leap upon some insect as it passes near, for their diet consists of insects.

2. Plant-eating bugs

Example: **The tarnished plant bug** (*Lygus pratensis* Linn.). Family, *Miridæ*.

Lygus pratensis Linn. In early spring soon after the fruit tree buds have begun to open it is not uncommon to find a trim, active brownish bug one-fifth to one-fourth inch long, mottled with red, black and yellow, and usually with a white V on its back between the bases of the

wings. These bugs may be found resting in the warm sunshine on green buds and young shoots of plants. They are shy and take flight when approached closely or disturbed. They are found on many kinds of trees, bushes and herbs, and they always choose the tenderest shoots or buds to feed upon.

The tarnished plant bug drills a hole into the green tissue of the plant bud, injects saliva into the hole and sucks the mixture of saliva and sap out for food. The effect of this operation on many kinds of plants is to kill or injure the tender bud or shoot so that its growth stops and the plant becomes stunted. This injury is especially severe on young nursery trees whose proper growth depends on the lengthening of one central stem. When the terminal bud on this stem is destroyed, a misshapen tree will result. Nurserymen call the result of the tarnished plant bug's work "stop-back" or "bush-head." In gardens the plant bugs often pierce flowers such as snap-dragons and asters, with the result that no seed will be borne on them. Vegetable crops like celery may be severely injured by punctures in the stalks.

Lygus pratensis adults continue to fly from plant to plant throughout spring and summer, to puncture the new growth of almost any kind of plant available. They get their food in this way. When the female is ready to deposit an egg she is more exclusive in her choice of plants. She usually flies to a composite flower such as horseweed, fleabane, daisy, golden rod or aster for this operation. Leonard Haseman has found that horseweed (*Erigeron canadensis*) is most commonly chosen by the female bug as a place of oviposition.

During the act of ovipositing, she rests upon the blossom and by means of her ovipositor, which consists

of four sharp lancets usually folded away like the blades of a jack-knife in a pocket beneath the abdomen, she thrusts a single egg down between the flowerlets in the blossom. A liquid flows from the ovipositor along with the egg and cements it to the side of a flowerlet. She visits many flowers during a period of several weeks and leaves an egg attached to each flowerlet that suits her fancy until she has exhausted her supply. During the weeks of oviposition, she alternates the task of egg laying with feeding and resting. The adult tarnished plant bugs may live and continue drinking the juices of plants for some weeks after the eggs are laid.

FIG. 55.—Tarnished plant bug. *a*, *b*, *c*, first three nymphal stages. (From Chittenden, U.S.D.A.)

The egg resembles so closely the plump, oval, developing seeds in the flower of the horseweed that it easily escapes notice. After an incubation period of from 7 to 10 days, the nymph bursts out from the upper end of the egg and rests upon the flowerlet until the chitinous covering of its body becomes firm. Then the nymphal bug begins to suck food from the tender flowerlets and to grow.

FIG. 56.—Tarnished plant bug adult and last stage nymph. (From Chittenden, U.S.D.A.)

It feeds upon the tender parts of the horseweed and grows for a period of from four to six weeks. At the end of this period, the adult form is attained. During the growth period the nymph molts 5 times, changing color and size with each molt. At first it is pale yellow and about 1 mm. long, then after the

first molt, it is green with spots of red and white. The green gradually changes to brown and the other colors become darker at each succeeding molt until the fifth and largest stage of the larva becomes brightly marked with spots of red, black and white. The fifth stage nymph is 4 mm. (nearly three-sixteenths inch) long and its wing pads are quite prominent on the back. In spite of the brightness of its colors the nymph is difficult to see among the seed clusters of the horseweed, for these have a mottled color effect also.

Protective coloration such as this is a condition very commonly found in nature when an animal is in its natural home, and in the case of plant-eating insects, it often helps in finding the true host plants of a species. The nymphs of *Lygus pratensis* run about over the surface of the plant during pleasant weather, exercising their muscles and finding new places to thrust in the beak and drink. The older nymphs are especially active and they sometimes wander to adjoining plants to explore new surfaces. At the end of their growth period the final molt takes place and the firm, bright-colored nymph becomes, within a few hours, a limp, pale adult with 2 pairs of wings lying on its back. In a day or so after the molt, however, the colors of the adult deepen to their final shades of brown, black and red. The surface of the body becomes firm so that the muscles attached to the inside of the body wall may be contracted and the bug is ready to fly to other plants.

Since the eggs of *Lygus pratensis* are not deposited on the plants all at once, but are deposited one at a time and over a considerable period of time, the young do not mature all at once. Thus the broods of the species in any locality are irregular and it is possible for a nymph

to mature before its parents die. Among many species of insects, it is quite commonly the case that one generation never sees the generation which has produced it, for the parents are dead before their eggs hatch. There are two generations each year of the tarnished plant bug and the adults of the second generation carry the species through the winter. They go into hibernation in late autumn to remain until spring warms up their bodies and makes them active again. They hibernate in such protected places as between the woolly leaves of mullein plants, in rock piles or wood piles under the loose bark of trees, among fallen leaves or rubbish. Many of the bugs do not have vitality enough to revive in the spring and some are eaten by prowling spiders and ground beetles which have become hungry and active during warm spells in winter. But enough of the bugs always survive to continue the species.

Lygus pratensis has become very widely distributed over the continents of the earth and has attracted the attention of so many entomologists in different countries that it has at various times been described as a new species. At least sixteen different Latin names were assigned to it. All of the names are, however, incorrect except the one used here, for it was the first one applied to the species.

Among the cultivated plants which the tarnished plant bugs puncture to secure food are apple, pear, peach, plum, cherry, quince, apricot, strawberry, currant, gooseberry, grape, blackberry, raspberry, potato, cabbage, turnip, celery, beets, beans, chrysanthemum, carnation, peony, aster, dahlia, zinnia, wheat, corn and oats. The effect of their puncture is very different on different kinds of plants. It seems to be very injurious to young fruit

trees. On the other hand, it does but slight damage to the horseweed on which the young sometimes feed in great numbers.

REFERENCES:

CROSBY, C. R., and LEONARD, M. D. Cornell Univ. Agr. Exp. Sta. Bul. 346, 1914.

HASEMAN, L. Mo. Univ. Agr. Exp. Sta. Research Bul. 29, 1918.

Only a few of the numerous other plant-eating bugs may be mentioned in passing over this group of the *Hemiptera*. The family **Lygæidæ** includes among others the

FIG. 57.—Chinch bug. (From Kellogg.)

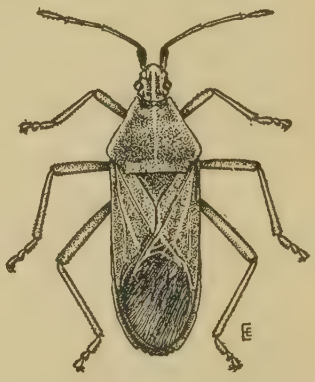


FIG. 58.—Squash bug. (From Crosby and Leonard.)

notorious "chinch bug" which is in some years a very serious pest of corn and certain other field crops in the Mississippi valley. The family **Coreidæ** includes the big, brown "squash bugs" so common on squash and melon leaves, the common red and black "box elder bug," the orange and black milkweed bug and others.

One group of plant-eating bugs contains small white and brown insects whose backs and wings present dainty lace-like patterns, and consequently these insects are

called "lace-bugs" (Fig. 210). They live in colonies usually on the lower side of the leaves of various plants and suck sap from the leaves for food. Some of our commonest species occur on sycamore, basswood, chrysanthemum, oak and rhododendron. The tiny black eggs are buried among the leaf hairs near or in a vein and the lace-bugs from birth to old age live a monotonous life on the leaves.

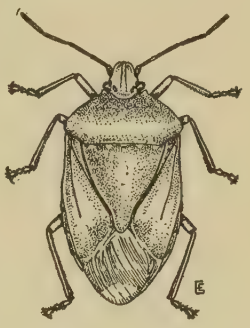


Fig. 59. — Stink bug. (From Crosby and Leonard.)

The family of insects known by the unpleasant name of "stink bugs" probably deserves the name more than other groups of *Hemiptera,* although most of the other families have odoriferous glands also. Most of us are acquainted with the odor of a stink bug either from having handled the bug or from having accidentally found it in a handful of blackberries just picked. The stink bugs are often fairly large and usually either brown or green in color. A few, like the "harlequin cabbage-bug" (or "calico-back" as it is sometimes called), are mottled with gay colors. Many of the species of this family puncture fruits and vegetables to suck sap, and some, like the harlequin cabbage-bug, are serious pests. Many others feed upon various insects and should be classed among the predaceous bugs.

3. Predaceous bugs

Example: The gray damsel bug (*Nabis ferus* Linn.). Family, *Nabidæ.*

Nabis ferus Linn. A pale brownish-gray, slender bug about one-fourth inch long and very narrow across the

shoulders is frequently present in meadows or other areas where grasses are allowed to grow tall. Although it is usually abundant in such places it is seldom seen even by keen observers, for it resembles very closely the seed masses of grasses and remains motionless for long periods, resting on the grass stems. This bug lives a lazy life, often waiting for its food to walk within reach, but the instant a motionless *Nabis* is approached closely by an unsuspecting leaf-hopper, an aphid or a plant bug, a pair of short, stout front legs moves swiftly out to grasp the victim and a sharp, powerful beak pierces its body.

FIG. 60.—*Nabis ferus* adult. (From Garman and Jewett.)

The name of damsel bug must have been bestowed upon *Nabis ferus* and upon the other members of the family *Nabidæ* because of their appearance, rather than their habits. Surely no one would class their habits as damsel-like. They prey upon many kinds of small insects which inhabit the meadow plants. While the gray damsel bug is primarily an inhabitant of the meadows, it is also present in gardens and cornfields. Professor Herbert Osborn found it destroying leaf-hoppers and the larvæ of meadow plant bugs. Professor H. Garman has found it sucking the blood of live aphids and caterpillars, such as the corn-ear caterpillar, on the corn plants. He says that it is present on all sorts of cultivated crops at most seasons of the year. The writer has found the adults on cabbage plants devouring aphids.

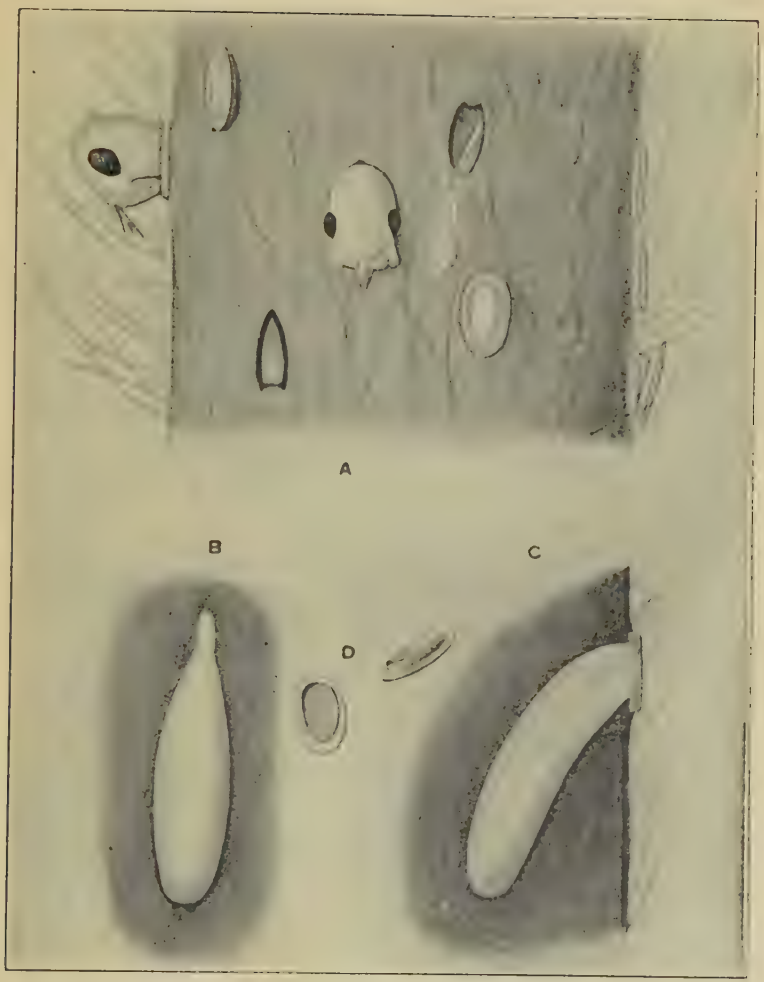


FIG. 61.—*Nabis ferus*. *A*, young coming from eggs in red clover stem; *B*, egg; *C*, side view of egg as seen after splitting the stem; *D*, two egg caps. (From Garman and Jewett.)

Let us trace the life cycle of the gray damsel bug through the year, beginning with the winter season. Only adults have been found to survive the winter. They hibernate under the protection of matted grass in the fields, in mulching on strawberries, under old cabbage leaves in the garden or under other shelter. In the spring, as soon as plant growth has started and aphids are abundant, the gray damsel bugs leave their winter quarters and fly to the growing plants to find food. After a several weeks' period of feeding, the egg laying season begins in late June.

Each female bug selects a green stem of clover, grass or other meadow plant, and by means of her sharp ovipositor cuts a vertical line of tiny holes into it. Into each hole, as soon as it is cut, an egg is guided by the ovipositor and the egg is pushed in so that it is completely buried in the tissue of the plant stem. The entrance to the hole is then covered with an oval, flat cap which seals it and protects the egg from injury. The damsel bug may deposit sixty or more eggs during the three weeks of her oviposition period. The eggs are kept moist by the plant sap during the six or more days that the embryo bug is developing. When ready to leave the egg the nymph bursts the delicate egg shell and pushes off the oval cap with its head. Then, after protruding its head from the hole for a short time, it struggles out of an embryonic sack which has enclosed its body while in the egg and climbs out upon the plant stem.

After resting a few hours from its struggles to gain freedom, the young damsel bug begins its career of slaughter. Its beak is sharp and stout even at this tender age and it may be seen attacking aphids twice its size. F. G. Mundinger has watched the young damsel bugs

feed and noted their predaceous character, even when one day old. They thrust their beaks with great precision into the abdomens of the aphids and suck out the blood. Sometimes the aphid in an attempt to escape will pull the nabid along bodily for a short distance, and succeed in freeing itself.

The young nabids are very hearty eaters and feed almost continuously during the days that are dry and

FIG. 62.—*Nabis ferus* just hatched. (From Garman and Jewett.)

warm enough for their activities. If no other food is available, they attack their brothers, and only the most successful fighters among them survive this cannibalistic custom. They also drink water by placing the tip of the beak into drops of water which collect on the surface of the plant.

Mundinger also watched them at their toilet, cleaning the antennæ and beak after the bloody feast. These parts were brushed and scraped clean by drawing them, one at a time, through the rows of spiny hairs which are attached to the outer ends of the front tibiæ. The two legs were brought together so as to make a brush which would completely encircle the appendage as it was drawn between the hairs.

It takes about twenty-five days and nobody knows how many meals to bring the gray damsel bug to the

fifth molt, when wings and maturity are gained. The first generation of the year becomes mature during late July and early August. After a few days of feeding and mating these adults start a second generation. Its life cycle is much like that of the first generation. The main difference is that the adults of the second generation go into hibernation each autumn and wait until the next spring to deposit the eggs and thus complete the life cycle. The members of the second generation become mature before the last of September. Their time is spent during the autumn in eating, seeking a mate and seeking shelter for hibernation. The following spring they capture food and store up energy for a month or more before the oviposition period. After the eggs are deposited, the females soon die. It is not known when the males die, but it seems probable that they last about as long as their mates.

The damsel bugs are considered as useful to man because they destroy many injurious pests of our field crops, such as aphids, leaf-hoppers, plant bugs and corn-ear caterpillars. The punctures made by damsel bugs for egg-laying in the stems of plants are injurious to the plants, but this injury is more than counterbalanced by the destruction of other insect pests which they effect.

The gray damsel bug is a very common species and is widely distributed around the earth in the north temperate regions.

REFERENCES:

OSBORN, HERBERT. Me. Agr. Exp. Sta. Bul. 276, p. 11.

GARMAN, H. Ky. Agr. Exp. Sta. Bul. 187, p. 585.

MUNDINGER, F. G. N. Y. State College Forestry (Syracuse), Tech. Pub. 16, p. 157.

In addition to the *Nabidæ* there are several other families of predaceous bugs, among them the **Cimicidæ** which contains the notorious "bed bug." The "bed bug,"

FIG. 63.—Bed bug. (From Kellogg after Riley.)

instead of confining its attacks to other insects, has established an appetite for human blood and by taking advantage of man's unconscious hours, it stealthily attacks his body. The members of the family **Reduviidæ** usually feed on the blood of other insects and are commonly found upon plants where they stalk their prey. A few enter the houses and even attack the bed bugs in their hiding places. The family **Phymatidæ**, known as ambush-bugs, usually hide in blossoms to capture insects visiting there and they undoubtedly kill many insects which are beneficial to us as pollen carriers. The small family **Anthocoridæ** contains small

FIG. 64.—Reduviid bug. (From Kellogg after Howard and Marlatt.)

bugs which are found in flowers, under the bark of trees, under rubbish or other objects where weaker or less agile

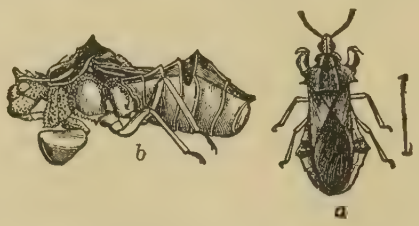


FIG. 65.—Ambush bug. (After Riley.) *a*, *b*, side and back views; *c*, front leg; *d*, beak.

insects may be found and pierced by the anthocorid's sharp beak. One species is often found destroying chinch bugs and corn-ear worms.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology*, Chap. XX, 1924.
IMMS, A. D. *General Textbook of Entomology*, pp. 328-354, 1925.

CHAPTER XV

ORDER HOMOPTERA

(Gr. homos, same; pteron, wing)

The members of this order are sucking insects with the beak arising from the rear of the under side of the head. The wings (when present) are of uniform thickness from base to tip and when at rest are held slanting down the sides of the body, not overlapping on the back. The young resemble adults in general form.

The members of the *Homoptera* vary greatly in appearance but practically all of them can be distinguished from other insects by the characteristic appearance of the lower side of the head which tapers toward the thorax and ends in a pointed beak that extends rearward between the front legs. The habits of the members of this order differ greatly but they have in common the one habit of spending most of their time on surfaces of living plants from which they suck the sap as food.

The cicadas are the largest of our common members of the *Homoptera,* often being over 2 inches in length. They are best known for the loud noise which they make among the trees in late summer. Cicadas are often erroneously called locusts. The name locust belongs to migratory species of grasshoppers which devastate areas of country by eating all the green vegetation before them. The locust plagues described in the Bible, as well as those of more recent times, were caused by species of grasshoppers.

Our North American representatives of the other groups of *Homoptera* are usually much smaller than the cicadas, some being barely visible to the naked eye, while most of them are from one-sixteenth to one-fourth inch in length. Since all of these smaller *Homoptera* live on the surfaces of plants and obtain their food by puncturing the plant to suck the juices, they constitute a very important group of pests. Their importance as pests is increased by the discovery that a number of plant diseases are carried by some species.

A few of their diverse habits will be illustrated in the following descriptions of examples of the subterranean, leaf-hopping and plant louse groups of *Homoptera*.

Subterranean group

Example: **The seventeen-year cicada** (*Tibicina septendecim* Linn.). Family, *Cicadidæ*.

Tibicina septendecim Linn. The seventeen-year cicada is a distinctly North American insect and lives only in that part of the United States east of central Kansas and north of Florida. It is remarkable chiefly because of its regular habit of remaining underground for nearly seventeen years while it is completing its growth. A most interesting account of its habits has been written by R. E. Snodgrass and the following description is taken largely from his account.

"Most of our familiar insects are regulated in their changes by the seasons of a single year. Hence we marvel at the 17-year life of the periodical cicada, the insect generally known as the 17-year locust. Yet there are common insects that normally take two or three years to reach maturity, and certain beetles have been known

to live for 20 years or more in the larval stage, though under conditions adverse for transforming to the adult form.

"Still there is something about the cicada that stirs our imagination as no other insect does. For nearly 17 years it silently toils in dreary tunnels underground. Then a springtime comes when countless thousands of the creatures issue from the earth, undergo their startling transformations and swarm into the trees. Now the very air seems swayed with the monotonous rhythm of their song, while the business of mating and egg laying goes rapidly on till the twigs of trees and shrubs are everywhere scarred with slits and punctures where the eggs are placed. In a few weeks the swarm is gone, and we may not live to see their progeny return.

"In the spring of their seventeenth year the cicadas burrow upward through the soil till they come to within a few inches of the surface. Recorded observations indicate that this migration takes place during the month of April. We know that the insects leave the earth during the latter part of May, so it seems that they must gather just below the surface and there await for several weeks the proper time for their emergence. Then, all of a sudden, as if at a given signal, the mass of them issues in swarms every evening for several days, and the ground is perforated with their exit holes.

"It is with a feeling akin to awe that we witness for the first time vast numbers of these insects issuing from the earth. Then we realize that they have all been quietly living beneath our feet these many years where we gave no thought to them."

In order to learn just how the young cicadas dig their tunnels through the soil without removing the earth and

bringing it to the surface, Snodgrass placed several in glass tubes filled with earth and watched them dig. "They demonstrated first that they do not burrow by plowing through the earth with the conical nosepiece that caps their faces, though the earth in the tubes was loose and might have been easily thus penetrated; nor did they claw their way along with the large front legs in any ordinary fashion. No; such is not the cicada's way; and what is not an insect's way it will not do even if it might. The cicada has inherited different traditions in the art of digging.

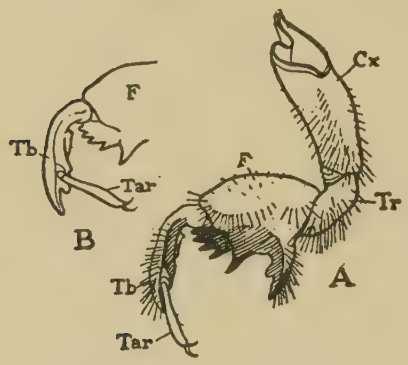


FIG. 66.—*A*, right front leg of mature nymph, inner side; *Cx*, basal joint or coxa; *Tr*, trochanter; *F*, femur; *Tb*, tibia; *Tar*, tarsus, with two terminal claws. *B*, showing the tarsus bent inward at right angles to the tibia, the position in which it is used as a rake. (From Snodgrass.)

"To understand its method of work, we must first study the construction of its front legs, for these are its principal tools." The femur of the front leg is much thicker than the others and is armed with some stout spines on its lower edge. The tibia is curved and terminates in a strong hooked point. The tarsus is attached to the inner face of the tibia above the hooked joints so that when it is turned in at right angles to the tibia, the tarsus is out of the way of the end of the tibia. (Fig. 66.) The cicada uses the curved points of the two tibiæ alternately, as picks with which to loosen the earth in front of it, the tarsi being turned back out of the way.

"When a small pile of loosened material accumulates, a rake is necessary. This is furnished by the tarsus now turned inward at right angles to the tibia. A little pile is scraped back toward the body, and—here comes the important part, the cicada's specialty—the little pile of rakings is grasped between the tibia and femur, the former closing up against the ventral spines of the latter, the leg strikes forcibly outward, and the fistful of loosened earth is mashed back into the surrounding earth. The process is repeated, first with one leg, then with the other. The digging cicada looks like a pugilist training on a punching bag. Now and then the worker stops and rubs its legs over the front of its head to clean them on the rows of bristles which cover each side of the face. Then it proceeds again, clawing, raking, gathering up the loosened particles, thrusting them back into the earth wall. Its back is firmly pressed against the opposite side of the growing cavity, the middle femora are bent forward till their knees are almost against the basis of the front legs, their tibiæ lying along the wing pads. The hind legs assume a normal position, though held close against the sides of the body. Thus—the cicada excavates a closed cavity by crowding the earth back into the surrounding earth."

In the spring of the seventeenth year the cicada digs to a place just beneath the surface and awaits there the proper time for emergence. In some localities where the soil is wet and the normal chambers at the upper end of the tunnels become filled with water or at least moldy, the cicadas continue their chambers up above the surface within closed turrets of mud several inches high. The turrets are constructed with soft pellets of clay or mud carried up from below by the front legs and pressed

firmly into place. The insects are thus able to rest high and dry until emergence time, when they leave the chambers by opening the top.

"By some feeling of impending change the young cicada waiting in its chamber, knows when the time of transformation it at hand. Somehow nature regulates the event so that it will happen in the evening, but once the hour has come, no time is to be lost. The insect must break out of its cell, find a suitable molting site and one in accord with the traditions of its race, and there fix itself by a firm grip of the tarsal claws. At the beginning of the principal emergence period, about the 21st of May, large numbers of the insects come out of their chambers as early as 5 o'clock; but after the rush of the first few days not many appeared before dusk."

"As they make their debut into the upper world—the crawling insects head for any upright object within their range of vision—a tree is the ideal goal if it can be attained, and since the creatures were born in trees there is likely to be one near by. Yet it frequently happens that trees in which many were hatched have been since cut down, in which case the returning pilgrims must make a longer journey perhaps than they anticipated. But the transformation cannot be delayed; if a tree is not accessible, a bush or a weed, a post, a telegraph pole, or a blade of grass will do. On the trees some get only so far as the trunk, others attain the branches, but the mob gets out upon the leaves. Though thousands emerge almost simultaneously, they have not all been timed alike. Some have but a few minutes to spare, others can travel about for an hour or so before anything happens."

"The external phase of transformation, more strictly

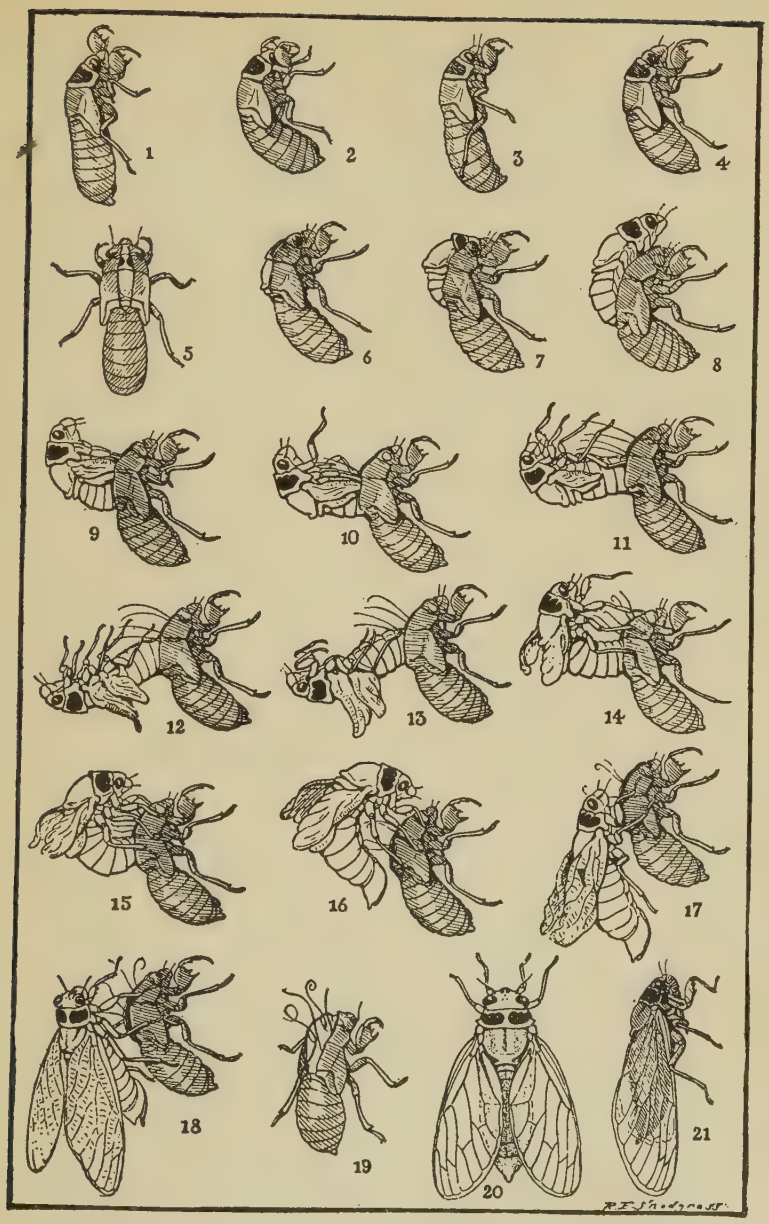


FIG. 67.—Transformation of the cicada from nymph to adult. (From Snodgrass.)

the shedding of the skin, has been many times observed. It is nothing more than all insects do. But the cicada is notorious because it does the thing in such a spectacular way, almost courting publicity where most insects are shy and retiring. As a consequence, the cicada is famous; the others are known only to prying entomologists.

"Let us suppose now that our crawling insect has reached a place that suits it, say on the trunk of a tree, or better still on a piece of branch provided for it in a lighted room where its doings can be more clearly observed. Though the insects choose the evenings for emergence, they are not bashful at all about changing their clothes in the glare of artificial light. The progress of this performance is illustrated in Fig. 67. The first drawing shows the insect still creeping upward; but in the next (2) it has come to rest and is cleaning its front feet and claws on the curry combs of its face, just as did those confined in the glass tubes to give a demonstration of their digging methods. The front feet done, the hind ones are next attended to. First one and then the other is slowly flexed and then straightened backward (3) while the foot scrapes over the side of the abdomen. Several times these acts are repeated calmly and deliberately, for it is an important thing that the claws be well freed from any particles of dry earth that might impair their grip on the support. At last the toilet is completed, though the middle feet are always neglected, and the insect feels about on the twig, grasping now here, now there, till its claws take a firm hold on the bark. At the same time it sways the body gently from side to side as if trying to settle comfortably for the next act.

"Thirty-five minutes were consumed in the above preliminaries and there is now a 10-minute interval of

quietude before the real show begins. Then suddenly the insect humps its back (4), the skin splits along the mid-line of the thorax (5), the rupture extending forward over the top of the head and rearward into the first segment of the abdomen. A creamy white back, stamped with two large jet black spots, now bulges out (6, 7); next comes a head with two brilliant red eyes (8); this is followed by the front part of a body (9), which bends backward and pulls out legs and bases of wings. Soon one leg is free (10), then four legs (11), while four long, glistening white threads pull out of the body of the issuing creature, but remain attached to the empty shell. These are the linings of the thoracic air tubes being shed with the—skin. Now the body hangs back down, when all the legs come free (12), and now it sags perilously (13) as the wings begin to expand and visibly lengthen.

"Here another rest intervenes; perhaps 25 minutes may elapse, while the soft new creature, like an inverted gargoyle supported only by the rear end of its body, hangs motionless far out from the split in the back of the shell. Now we understand why the insect took such pains to get a firm anchorage, for should the dead claws give way at this critical stage the resulting fall most probably would prove fatal.

"The next act begins abruptly. The gargoyle moves again, bends its body upward (14), grasps the head and shoulders of the slough (15), and pulls the rear parts of its body free from the gaping skin (16). The body straightens and hangs downward (17). At last we behold the free imago (=adult insect), not yet mature but rapidly assuming the characters of an adult cicada. The new creature hangs for a while from the discarded shell-like skin, clinging by the front and middle legs, some-

times by the first alone, the hind ones spread out sideways or bent against the body, rarely grasping the skin. The wings continue to unfold and lengthen, finally hang flat, fully formed, but soft and white (18). Here the creature usually becomes restless, leaves the empty skin (19), and takes up a new position several inches away (20).

"At this stage the cicada is strangely beautiful. Its creamy-yellow paleness, intensified by the great black patches just behind the head and relieved by the pearly flesh tint of the mesothorax, its shining red eyes, and the milky, semitransparent wings with deep chrome on their bases, make a unique impression on the mind. There is a look of unreality about the thing, which out of doors becomes a ghostlike vision against the night. But, even as we watch, the color changes, the unearthly paleness is suffused with bluish gray, which deepens to blackish gray. The wings flutter, fold against the back, and the spell is broken—an insect sits in the place of the vanished specter.

"The rest is commonplace. The colors deepen, the grays become blackish and then black, and after a few hours the creature has all the characters of a fully matured cicada. Early the next morning it is fluttering about, restless to be off with its mates to the woods.

"The time consumed by the entire performance, from the splitting of the skin to the folding of the wings above the back, varied with different individuals, observed at the same time and under the same conditions, from 45 minutes to one hour and 12 minutes. Most of the insects had issued from the cast off skins before 11 o'clock at night, but occasionally a straggler might be seen in the act as late as 9 o'clock the following morning. Such were

probably belated arrivals who over-slept the night before."

"The adult 17-year cicada has a thick-set body, the forehead is wide, with the eyes set out very prominently on each side. He is distinctly but not strikingly colored. The back is plain black; the eyes bright red; the wings shiny, transparent amber with strongly marked orange-red veins; the legs and beak are reddish and there are bands of the same color on the ventral rings of the abdomen. Each front wing is branded with a conspicuous brown W toward the tip." Superstition explains this as meaning war in the year of their appearance above ground.

"The male cicada is noted for his 'song,' yet his music is of an instrumental order rather than vocal. He carries a pair of large drumheads beneath the bases of his wings, the ridged, parchment-like surfaces of which are thrown into rapid vibration by a pair of pillarlike muscles in the front of the abdomen. Below the drums, between the thoracic and abdominal divisions of the body on each side, is a large cavity with tense membranes on its walls which most probably act as resonators. The cavities are closed below by a pair of large flaps projecting back from the thorax, but they can be opened by the elevation of the abdomen.

"The female has no drums, and consequently is doomed to keep silence; but no one has yet discovered that she possesses ears, so it seems she also does not have to listen to her noisy mates. Her chief distinction is her ovipositor, a swordlike instrument used for inserting her eggs into the twigs of trees and bushes. Ordinarily it is kept in a sheath beneath the rear half of the abdomen, but when used can be turned forward by a hinge at its base. The ovipositor consists of two lateral blades and

a guide rail above. The blades excavate the egg nests in the wood and then the eggs are passed into the nests through the space between the blades."

"It was formerly supposed that the cicadas take no food during the brief time of their adult life, but we now know—that they do feed abundantly by sucking the sap

FIG. 68.—Female cicada depositing eggs. (From Snodgrass.)

from the trees and bushes on which they live. The cicada is a large relation of the aphids, the scales, and other insects of the sucking order (*Hemiptera* and *Homoptera*) and like them has a beak for piercing the plant tissues and drawing the sap up to its mouth. But, unlike the aphids and scales, the cicadas seldom cause any visible damage to plants by their feeding.

"During the first two weeks of June the woods were full of the 'locusts' and the noise of their singing. The

song has no resemblance whatever to the shrill, undulating screech of the annual locust so common in August and September and known as the dog-day cicada. The song and all the notes of the large variety of the 17-year cicada are characterized by a burr sound and at least four different utterances may be distinguished."

"The cicadas lay their eggs in the twigs of trees and shrubs and frequently in the stalks of deciduous plants. They show no particular choice of species except that conifers are usually avoided."—"The eggs are not stuck into the wood at random, but are carefully placed in skillfully construced nests which the female excavates in the twigs with the blades of her long, curved ovipositor. These nests are perhaps always on the under-surfaces of the twigs, unless the latter are vertical, and usually there are rows of from half a dozen to twenty or more of them together."

"Each nest is double; that is, it consists of two chambers having a common exit, but separated by a thin vertical partition of wood. (Fig. 69.) The eggs are placed on end in the chambers in two rows, with their head ends downward and slanted toward the door. Generally there are 6 or 7 eggs in each row, making 24 to 28 eggs in the whole nest, but frequently there are more than this. The wood fibers at the entrance are very much frayed out by the action of the ovipositor and make a sort of fan-shaped platform in front of the door, where the young shed their hatching garments on emerging from the nest. This mutilation kills many twigs, especially those of oaks and hickories, the former soon showing the attacks of the insects by the dying of the leaves. The landscape of oak-covered regions thus becomes spotted

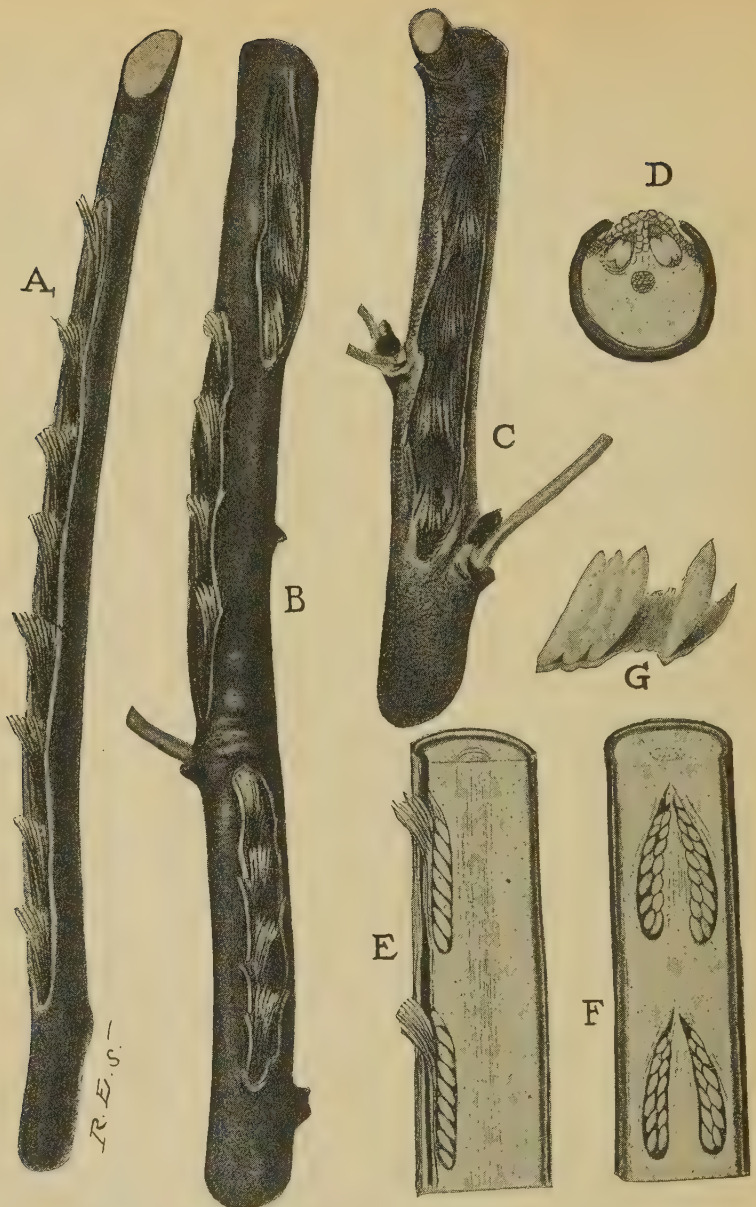


FIG. 69.—*A, B, C,* twigs of dogwood, oak and apple containing rows of cicada egg nests; *D,* cross section of twig through an egg nest showing the two chambers, each containing a double row of eggs; *E,* vertical section through two egg nests showing the rows of slanting eggs and the frayed lip of the opening; *F,* horizontal section showing each chamber filled with double row of eggs. (From Snodgrass.)

all over with red-brown patches which often almost cover individual trees from top to bottom. Other trees are not so much injured directly, but the weakened twigs often break in the wind and then hang down and die." A cicada may deposit from 400 to 600 eggs before exhausting her supply.

"From the time that egg laying was at its height, about the 10th of June, the din of the singing in the woods began to diminish. Many insects were from the first killed or mutilated by birds or small mammals; now the ground became strewn with dead bodies or with insects still living, but hopelessly injured and dismembered."

"By the 17th all was over; the great horde of insects that emerged from the earth and underwent such spectacular transformations only three or four weeks ago was gone. There was no evidence of the late swarm of visitors except that of the scarred twigs on the trees and bushes and the red-brown patches of dying leaves that everywhere disfigured the oaks and hickories."

From those scarred twigs there emerged about seven weeks after egg-laying a host of new cicadas. Watching at the door of one of the nests Snodgrass observed a tiny head come poking out of the narrow opening. As soon as the outside is gained the little creature twists and heaves until it splits the enclosing sac which insects wear within the egg. In less than a minute the new cicada is free from its sac and begins to run about in the groove of the twig containing its nest. Soon it goes outside on the smooth bark. Here any current of air is likely to carry it off or it may fall from the smooth bark. At any rate, very shortly after emerging the most of them disappear from the trees, due to their inability to hold on.

Upon reaching the ground they at once get below the surface by entering the first crevice met in running about.

The life of the cicada while in the ground is not so well known. It is a difficult problem to observe a creature buried in the earth among the tree roots for a period of 17 years. Of the many attempts made to follow definite individuals through the entire period and thus prove the length of their life a single experiment recorded by Marlatt was successful. This was carried on at the United States Department of Agriculture grounds at Washington from 1889 to 1906, when the cicadas emerged in due time. Marlatt states that the nymph remains most of its life in a little oval chamber which it constructs in the earth.

FIG. 70. — Young cicada nymph ready to enter the ground. (From Snodgrass.)

At the border of the chamber is a small root usually one-sixteenth to three-sixteenth inch in diameter. The walls of the chamber are solidly packed earth except at the upper end where the rootlet is included. The size of the chamber varies with the size of the nymph and the compactness of the surrounding earth. At first the chamber is no larger than a bird shot but it is gradually enlarged to accommodate the growing occupant. Its food is the sap from the root which is punctured by the sharp beak. Remaining quietly resting or working to enlarge the chamber to accommodate its slowly growing body, the young cicada remains in the one place for years. When the temperature becomes too low for activity the insect hibernates and when the ground warms up activity begins again. Usually the cicada need dig only 8 to 18

inches below the surface to find a suitable rootlet to supply its needs, but occasionally an individual is found 2 feet down below the surface.

In spite of its many years of growth the 17-year cicada molts its skin only six times; the same number as those cicadas which complete the life cycle in a few years. Its final size is no greater than the short lived species; in fact it is smaller than many of them. We can only account for its long growth period by saying that the 17-year cicada is slow.

With the clearing of timber land and cultivation of larger areas of the soil in the eastern half of the United States where this cicada lives it is becoming less abundant. However in those areas which are still largely wooded, the cicadas seem to be as plentiful now as they were a hundred years ago. Their emergences have been recorded in so many localities for so long a time that the United States Bureau of Entomology has been able to map out the various broods and to predict the year in which the cicadas will emerge in any county.

References:

Marlatt, C. L. U. S. Bureau of Ent. Bul. 71.
Snodgrass, R. E. Smithsonian Report for 1919, pp. 381-409.

There are 75 or more different kinds of cicadas in our country, some larger and some smaller than the 17-year cicada. None of them are known to have such long lives as the latter, but we know very little concerning their life histories yet. There are broods of our common big black and green cicada coming out of the ground every summer in any locality but it is probable that each individual has been in the ground several years.

LEAF-HOPPER GROUP

Example: **The Rose Leaf-hopper** (*Empoa rosæ* Linn.)
Family, *Cicadellidæ*.

A few weeks after the roses have begun to bloom their foliage very commonly becomes unhealthy in appearance. The bright green color gradually is changed to a dull gray as the chlorophyll is removed from the tissues by hundreds of tiny insects living on the under surface of the leaves. If you wait until the injury to the leaves has become quite noticeable from a distance, you may approach and examine the leaf only to find that the insects have hopped and flown away out of your vision; but if you examine them early, when the leaves begin to be spotted before the insects have completed their work, you will find upon the lower surface a colony of tiny, white or pale green elongate insects quietly sucking the juices from the leaf. They vary from one-twenty-fifth to one-eighth inch in length according to their ages. The older ones are more active and will run about on the leaf or jump into the air to alight on another leaf, but the younger ones are not easily disturbed from their feeding positions. They seem to feed all the time for several weeks and during that time become about three times their original length. The rose leaves during that time lose much of their substance due to the constant drain on their supply of sap and the removal of so large a part of the chlorophyll. Since they no longer manufacture much food for it the whole plant becomes weakened when the leaves lose their green.

The rose leaf-hoppers which cause this injury are sometimes present by the thousands on a single rose bush, but more commonly a hundred or so individuals popu-

late a bush. If the thousands were always present there would soon be no rose leaves for their future generations to feed upon and consequently no future generations of

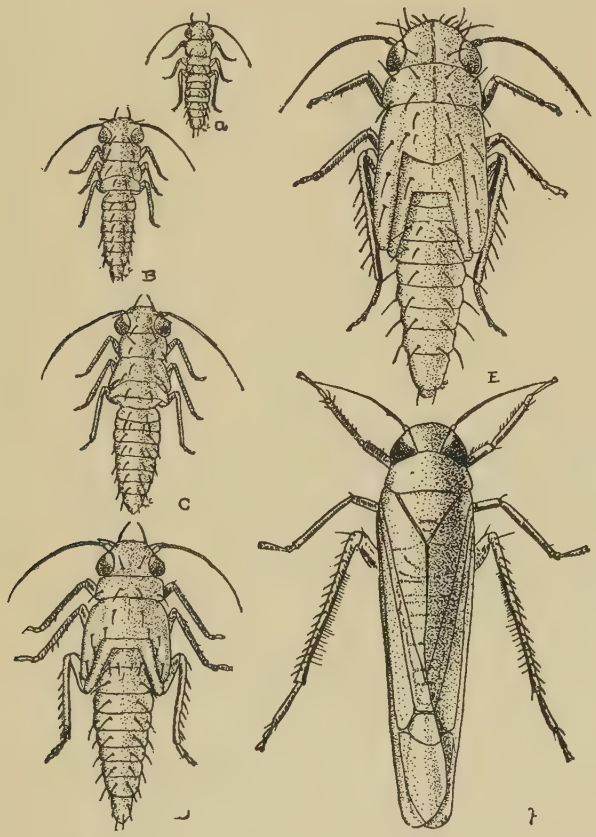


FIG. 71.—The Rose Leaf-hopper, *a, b, c, d, e,* nymphal and *f,* adult stages. (From Childs.)

hoppers. It is true that they feed upon other plants of the rose family and future generations might exist on those plants unless they in turn were destroyed. But

nature seems to have developed in the leaf-hoppers an instinct for preserving their favorite host-plant, the rose. For as soon as the young which have hatched on the rose bushes become adults and gain their wings the most of them fly to apple trees (usually large apple trees) and settle on the under side of the lower leaves. Here, with a much greater food supply and small danger to the host plant, a second generation of hoppers grows up. If no apple tree can be found during their migration the leaf-hoppers may be content to raise their families on the foliage of strawberry, hawthorn or even dogwood, but they prefer apple. When the second generation of adults has grown in late summer most of them return to the rose bushes to lay the eggs which are to keep the species alive through the winter. If they do not find rose bushes they will deposit the eggs in the canes of bramble fruits, such as blackberry and raspberry, or in the apple bark, or in strawberry runners.

The form in which the rose leaf-hopper survives the winter is the egg. It is a tiny white banana-shaped egg about one-fiftieth inch long and is pushed into its place in the stem so carefully that the bark does not split but forms an oblong blister over it for its protection. Just one egg is placed under each blister, but the mother may lay about 16 eggs and place them under a chain of blisters extending single file along the stem, or she may bunch several of them in a group and separate the others. The egg stage lasts from about October to early or mid-May when the leaf buds of the rose have unfolded. Some eggs hatch earlier than others, so that some of the young are a week or two old before the last of their brothers and sisters has come out from the egg shell.

If you have never seen an egg travel by its own force

you should watch one of these leaf-hoppers just before hatching. There is a tiny puncture near the blister in the bark made by the mother in placing the egg. When about to hatch, the egg, or more truly speaking, the young nymph within the pliable egg shell, squeezes through the puncture until all but the tip of the egg is hanging out in the air. Not until this position outside the bark has been reached does the egg begin to open. Then the shell breaks at the head end, which is pointed outward from the bark, and the tiny bristles on the young hopper's head appear through the opening. Other bristles and spines farther back on the body aid in driving the body forward as it bends from side to side in the shell. It works its way out of the shell much like a head of barley travels up your sleeve. For a few moments the newly emerged insect rests with the tip of its abdomen held in the old shell while the covering of the thorax and legs becomes firm enough to support the muscles. Then a violent wriggling brings the insect away from the egg shell onto the stem. The entire process has taken place in about 20 minutes. Following a short rest on the stem the young hopper begins wandering about in search of a leaf. Having found a leaf he becomes established near one of the main veins on the undersurface and begins to feed at once. Unless so many of his young relatives settle on the same leaf that the food supply gives out he will probably remain on the same leaf during his entire growth period. If food becomes scarce he will move to a nearby leaf and settle down.

The leaf-hoppers, like other *Homoptera,* pierce the leaf covering with the needle-like mandibles and maxillæ and suck out the juices. The green coloring matter from the cells pierced by the beak is sucked into the stomach

with the plant juice. The indigestible part of this food passes on through the intestine and hoppers have the habit of discharging excreta in a tiny greenish-black droplet every few moments. When disturbed the abdomen is arched and the anterior part drawn forward with a quick jerk, whereupon a droplet of excreta will be thrown out to a distance of many times the length of the insect. Possibly this bombardment is useful against predaceous insects.

The rose leaf-hoppers are of the shape shown in Fig. 71. They are only about one-twenty-fifth inch long at first but grow to be three times that length. They are white with bright red eyes at first, but the red color disappears at the second molt, leaving the insect entirely pale greenish-white. The leaf-hopper molts its skin five times as it grows. Like the grasshopper's and the bug's its wing pads begin to develop after the second molt and become more noticeable on the back after the later molts until the fifth molt uncovers the wings of the adult.

During the last half of June, about one month after the winter eggs hatched, the young have become full grown and change to adults.

For several days after the unfolding of the wings the adults are content to remain on the leaf which has been their home, but soon they become restless and begin to fly. The flight is most noticeable in late afternoon and evening when the wind has died down. Then the air seems full of the tiny creatures flying slowly about in every direction. The migration may continue for a week or more until at the end of that period almost none remain on the rose. Undoubtedly the most of the migrants never reach a proper food plant for continuing the species but enough are successful in their migration to produce

a large second generation on the apple foliage. After settling on the apple leaves, the immigrants for several days spend their mornings in mating and the remainder of the day in feeding and resting.

The adult insects are very easily disturbed and extremely active. If you approach them they sense your presence before you are within ten feet of the tree and immediately begin to fly about. The ability to start

FIG. 72.—Leaf-hopper eggs inserted into mid-rib of leaf, partly uncovered by cutting away leaf tissue. (From Ackerman, U.S.D.A.)

flight very quickly is quite characteristic of the leaf-hoppers. They possess long jumping hind legs by means of which their bodies may be thrown out into the air to the distance of 100 or more times the body-length. While in the air the wings may be brought into use to continue the flight. Only the leaf-hoppers which have passed the third molt have the ability to hop. Younger ones move only upon necessity and then they walk.

The eggs which are to produce the second generation are not placed under the bark like the winter eggs, but instead are inserted into the petiole or mid-rib of the leaf where they are buried beneath the outer covering of the leaf. The summer eggs also develop much more

rapidly than the winter eggs, for 25 days is the average length of the egg stage in summer while seven and one-half months is the average in winter.

Some observations on the length of life of the adult rose leaf-hoppers which were made by Leroy Childs show that the males of the first generation died within ten days after mating. The females which produced young, lived from a month to a month and a half after mating. The unmated females lived much longer and in one case as long as 116 days after hatching or nearly three months after the normal mating time. Adults of the second generation seem to live much longer than those of the first generation and probably perish in autumn only when the sap ceases to flow in the leaves or heavy freezes occur.

The eggs which were placed in the leaves begin to hatch about the middle of July and the young hoppers continue to emerge from them until early August. The young of this generation become full grown in about 15 days or one-half the time required to raise their parents. Probably this speedy growth is due to the warmer prevailing temperature of July and August. In early August adult leaf-hoppers begin to appear and continue to increase until the end of the month. They have a long period in which to feed, emigrate to the rose bushes, mate and lay the winter eggs. The flight from the apple trees is not confined to a few days, nor do the hoppers seem to fly in great numbers, but, rather, they gradually disappear from the apple and appear on the rose bushes. As stated above, many do not find their favorite host plant, the rose, but alight on some other plant and if it is a suitable substitute for rose they remain to deposit the winter eggs in it. The majority of winter eggs, however, are found in the young growth of rose stems.

Female rose leaf-hoppers have long, sharp ovipositors concealed in a pocket beneath the abdomen. When in use the ovipositor is withdrawn from its pocket and pushed into the plant. After the proper cavity has been made the egg passes between the slender parts which compose the ovipositor until the cavity is reached and the bark over it becomes raised like a blister. The ovipositors of females of the second generation are darker in color than those of the first and this darker color is due to a heavier deposit of chitin which makes the structure hard. This difference is in accord with the fact that the second generation deposits eggs in woody tissue while the first generation deposits them in tender leaf tissue.

References:

Childs, Leroy. Oregon Agr. Exp. Sta. Bul. 148.
Lathrop, Frank H. N. Y. Agr. Exp. Sta. (Geneva) Bul. 451.
Ackerman, A. J. U. S. D. Agr. Bul. 805.

There are more than seven hundred different kinds of leaf-hoppers in the United States alone and our country has no monopoly on leaf-hoppers. With the exception of aphids, they are the most numerous of the *Homoptera* found on green vegetation. They may be seen hopping from plant to plant in any pasture, garden, orchard, vineyard, cultivated field or weed patch, during the entire growing season. During warm spells in winter some of them may be aroused to hop out from the grass tufts where they hibernate.

A group of insects resembling some of the leaf-hoppers in appearance is the group known as "spittle insects." These insects, which live on the stems and leaves of grasses, shrubs and trees, have the curious habit, before they become fully grown, of surrounding their bodies

FIG. 73.—Spittle-insect, showing stages of spittle production. (From Kellogg.)

FIG. 74.—Tree-hopper. (From Slingerland and Crosby.)

with a foamy mass of plant sap which appears like a mass of spittle on the plant. In producing this, the spittle insect sucks more sap than it can use for food and expels the surplus, into which air bubbles are drawn, leaving it in a frothy condition. The maker of this frothy mass is often protected by it from the spying eyes of parasites

and from inclement weather. Spittle insects belong to the family *Cercopidæ*.

Among the hopping insects commonly found on plants is another group known as the "tree-hoppers" or *Membracidæ*. Although they suck the sap like leaf-hoppers, they are usually found upon the stems and branches of plants more often than upon the leaves. The front end of the body is usually provided with one or two "horns," which give the insect the appearance of a thorn or twig stub, as it rests on the plant. Some species of tree-hoppers make slits in the bark and wood of fruit trees in which to deposit their eggs and the wounds so made always heal in such a manner as to leave large, unsightly scars on the branches.

PLANT-LICE GROUP

Example: **The Apple-grain Aphis** (*Rhopalosiphum prunifoliæ* Fitch). Family, *Aphididæ*.

Every fruit grower who has examined the opening buds of his apple trees in spring has seen the little oval green plant-lice about one-sixteenth inch long which are collected on the green tips of the buds. These insects are known as the Apple-grain Aphis. They are found also on the opening buds of other trees of the apple family, such as pear, hawthorn and crab-apple. They are very small insects in size but grow large in numbers and live peacefully together in flocks. At first there are very few on the bud. As more young are born the size of the flock may increase until the entire unfolded bud becomes covered with a hundred or more members of the flock. When the leaves become too crowded some aphids wander off to other leaves and start flocks on those leaves.

Aphids seem to have specialized in large numbers or at least in a high rate of reproduction. A new generation is born about every two weeks in chilly weather when the average temperature is 60°, and the time ranges from that to every 7 days in hot weather (80°).

FIG. 75. — Newly hatched aphids on apple bud. (From Slingerland and Crosby.)

The rate of reproduction is so rapid that the possible progeny of a single aphid in a season (if none died an unnatural death) would be counted in billions. Of course no such number ever survives because most of the aphids are destroyed by rains, other insects, etc., and each spring we find only about the same number as in other years. Let their destructive enemies be absent a few days, however, and the aphids soon cover the leaves of the host plant.

The Apple-grain Aphis lives on apple trees during the cool months and on grasses during the warm months. In early June the aphids migrate to grasses of various kinds and during October a migration to apple trees from the grasses occurs. When you consider the facts that grasses are the most widespread and abundant green plants in the summer and that trees unfold more green leaf surface more quickly in the spring than other plants, it seems as though the aphids have very appropriate migration habits for the production of immense numbers of individuals. At least they have the maximum food supply for the entire growing season. In southern states where the grasses continue to grow during the winter some

aphids remain on grasses all year, but in the northern states they migrate to the trees in autumn and hibernate in the egg stage. It is only in the egg that they can withstand severe, and continual freezes.

Correlated with their appropriate food habits the aphids have very remarkable adaptations for migration. They are most commonly wingless even in the adult stage of life, but enough aphids seem to inherit the tendency to grow wings at the proper time, so that the migrations are flights. Wings never appear on the individuals which hatch from the winter eggs, but most of the next generation have wings, a few of the third generation get wings, and all of the fourth generation get wings. The winged ones instinctively fly to grasses and consequently there are only the four generations passed on apple trees in spring. The fifth, sixth, seventh and succeeding generations which are passed on grasses, have a decreasing number of winged individuals and by the time the seventeenth generation has been reached, no wings are found. The fact that wings persisted longest in the progeny of certain individuals makes wings seem like inheritable structures.

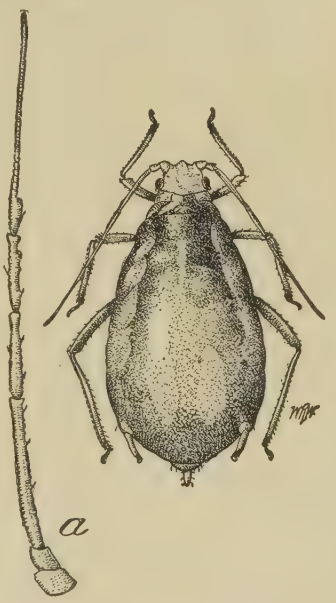


FIG. 76.—Wingless form, Apple-grain Aphis. (From Davis, U.S.D.A.)

Some adults appear during the summer generations

which are intermediate between the winged and wingless forms. These intermediates have dwarfed or partly formed wings which are of no use for flight. In other characters, such as length of larval growth period, they resemble winged forms, while in reproductive activities they resemble wingless forms. In the autumn, after the seventeenth generation, when all winged forms have dis-

FIG. 77.—Winged form, Apple-grain Aphis. (From Davis U.S.D.A.)

appeared from the grasses, then the production of winged forms begins again, and the number increases very rapidly until nearly all are winged in October. These winged ones have the instinct to find trees, and soon the old apple leaves are found by them. During this migration the air often seems filled with the tiny creatures for days at a time. The progeny of the fall migrants to apple trees are wingless forms and these lay, on the twigs, the eggs which will produce the wingless first generation the following spring. There is then a distinct correlation between migration to different food plants and the production of wings among aphids.

Another remarkable adaptation of aphids is found in their mode of reproduction. Most insects hatch from eggs which were fertilized by the male parent and then deposited by the mother near the favorite food of the young. Such a method requires time for the male to find the females and fertilize the eggs. Also eggs deposited on the plants are, during their developmental period, subject to the dangers of extreme changes in moisture and temperature, and to destruction by enemies. Aphids avoid such delays and dangers to rapid reproduction during the summer by development through the egg stage within the mother's body and without fertilization by males. The young are born fully formed and ready to feed like their parents. No time or material need be wasted in producing egg shells for protection of the egg. Since no males are needed all individuals become mothers and thus every aphid can produce young by itself alone. This method of reproduction is used by the aphids until the cold weather of autumn stops the growth of green plants. Then a generation is produced which contains males and females. The eggs, fertilized by the males, are deposited on the apple twigs, and remain unhatched until the following spring. They are covered with a glossy black shell three layers thick, which protects the embryo within the egg from the weather. Males are not formed excepting in autumn and no eggs are deposited outside the mothers except when winter approaches to remove the food supply.

The food of aphids is the juice within the food tubes (vascular bundles) of leaves, young shoots or green stems of plants. It is a food usually rich in sugars which are manufactured in the leaves and are being carried in the tubes to other parts of the plants. The aphid has a long,

flexible, needle-like beak which can be pushed through the outer covering of the plant to tap the tubes within. The needle-like beak itself contains two canals extending its entire length; one, a food canal, is used to suck up the food into the pharynx and thence it passes into the stomach; the other, a salivary canal, carries a liquid which we call saliva from glands in the thorax down into the plant. Its use is not yet known. Aphids commonly take more juice from the plant than they use and the excess passes along the intestine to the anus from which it is expelled as drops of clear syrup known as honey dew. This substance frequently spreads over the surface of objects below the aphid colony giving it a glistening sticky coating. Honey dew is used as a confection by many ants and is often gathered by bees, but makes a poor quality honey.

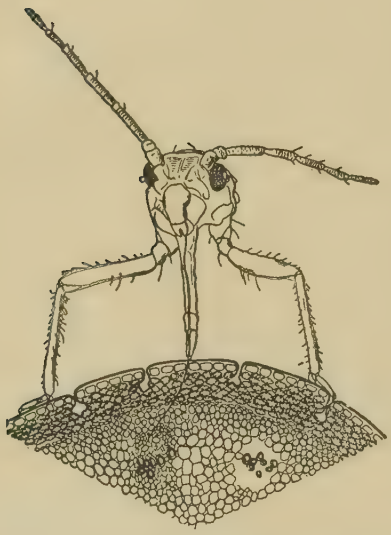


FIG. 78.—Aphid feeding, showing beak inserted into plant tissue. (From Slingerland and Crosby.)

Eggs of the Apple-grain Aphis are deposited on or near the fruit buds or in little depressions of the twigs and small branches of the apple tree. They appear like black, oval, glistening specks and are sometimes crowded together so that a hundred or more occur on one small branch. Each egg-laying aphid, however, produces very

few eggs, usually one to three; so the large numbers of eggs grouped together are due to the colonial instinct of the mothers.

The aphids which hatch from the eggs in early spring are known as stem-mothers, for they are the stems from which the numerous summer branches of the species arise. A stem-mother becomes mature in about 13 days after bursting out from the egg. She, and her progeny also, molt only four times during the growth period. As soon as mature she begins to produce young at the rate of about 8 per day and continues this until she has produced about 100 young aphids. (It should be remembered that there is much individual variation in the time of growth, number of young, etc., in aphids as in other insects, so the figures given are only approximate estimates.) After producing her young aphids, the stem-mother may continue to feed for a few days and then dies. Some of her children fly away. Some remain wingless and produce grandchildren in the colony on apple leaves. More of the grandchildren develop wings and disappear until finally all have developed wings and deserted the apple tree for grass plants. They may choose any one of a

FIG. 79.—Aphid eggs on apple twig. (From Slingerland and Crosby.)

large number of kinds of grasses, including oats, wheat, rye, barley, timothy, blue grass, crab grass and various other meadow grasses. The aphids locate mainly on the stems and lower portions of the leaves of grasses where they are not noticed by the casual observer. During hot, dry spells the aphids stay close to the ground where they may keep cooler and be shaded. The wingless ones wander from plant to plant when the colony outgrows the food supply on a plant. During the summer an individual becomes mature in about a week and produces 25 to 30 young. The winged ones require about two days longer to become mature than do the wingless ones. The winged ones also produce fewer young (about 16). The production of winged forms therefore slows down the rate of reproduction of the species.

A peculiarity in the life cycle of this species is found in the manner of production of the two sexes in autumn. All the fall forms come from wingless mothers. One of these mothers may produce either winged fall migrants which will fly to apple trees, or wingless forms which will remain on the grasses. She may also produce toward the end of her life several winged males. The males are produced thus in the same generation with the fall migrants. The fall migrants fly to apple trees and there produce wingless females. These will mate with the males of the preceding generation which, when mature, fly to apple trees. Thus the males are members of the generation preceding that of the females with which they mate.

Aphids in most species have a pair of small tubes attached to the top of the abdomen extending out like a couple of tiny guns trained to the rearward. These tubes, called cornicles, are not found on other kinds of insects,

and a few species of aphids do not have them. The cornicles are the outlets for a glandular secretion which in some cases at least is shot onto the faces of insect enemies to stop their attack. The cornicles are rather short on the Apple-grain Aphis and their use has not been observed.

REFERENCES:

BAKER, A. C., and TURNER, W. F. *Jour. Agr. Research,* Vol. 18, pp. 311-324.

DAVIS, J. J. U. S. D. A. Bul. 112, "The Oat Aphis."

A great many other species of aphids pass through changes similar to those undergone by the above species. Some of them we find for a time infesting the tender shoots of some particular kind of plant and later we find no trace of them there for they have flown to some unknown alternate host plant. A number of species excrete a white waxy material from tiny wax glands located on many parts of the body. Their appearance, due to the matted threads of white wax, has given rise to the name "woolly aphids." One of the woolly aphids is quite commonly found on apple and elm trees. On the apple trees it sometimes crawls down to the roots and forms galls on them which injure the trees seriously. Other species cause galls of many curious shapes to form on the leaves of various plants. One group of aphids known as *Phylloxera* has become well known, because one of its species has destroyed millions of acres of vineyards in France and California by forming galls on the grape roots which later decay.

In addition to the true plant lice of the family *Aphididæ,* there are three other families of plant lice which should be mentioned. The *Psyllidæ,* known as "jump-

ing plant-lice," are small leaping insects which appear like miniature cicadas. They often live in galls on plants, especially on hackberry, ash and other trees. Some feed openly on the leaves and fruits of pear and apple trees, where the young congregate in flocks like aphids. The *Coccidæ* are scale insects and mealy bugs. They infest

FIG. 80.—A psyllid, or jumping plant-louse. (From Slingerland and Crosby.)

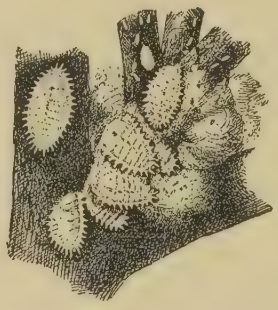


FIG. 81.—Mealy bugs. (From Marlatt, U.S. D.A.)

the bark and leaves of plants, usually becoming immovably attached to the surface, losing their legs at the first molt. The San Jose scale, Oystershell scale and numerous other species secrete a waxy scale which completely covers the body and appears like a small eruption of the bark. Mealy bugs are covered with a powdery form of white wax. They retain the legs and move slowly about on the plants. The Aleyrodidæ are tropical insects which, however, are pests in greenhouses and on house plants

in temperate regions. The adults of our greenhouse species are tiny "white flies," often flying in clouds from the lower side of plant leaves. The young become at-

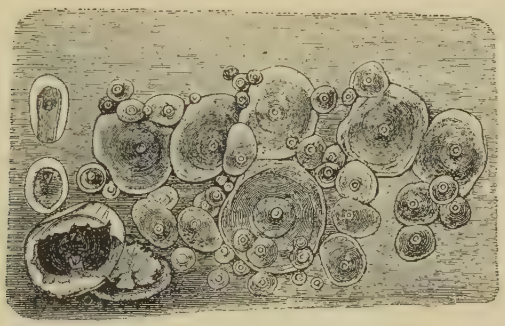


FIG. 82.—Wax covered scale insects. (From Marlatt, U.S.D.A.)

tached to the leaves like scale insects and have a fringe of wax around the border of the body. All of the above-mentioned families may become pests like aphids, when they are present in large numbers.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology,* Chap. XXI, 1924.
IMMS, A. D. *General Textbook of Entomology,* pp. 354-373, 1925.

CHAPTER XVI

ORDER LEPIDOPTERA

(Gr. lepis, scale; ptera, wings)

The members of this order usually have in the adult stage two pairs of large wings densely covered with scales. The adults are known as moths and butterflies. The young are somewhat worm-like in form and are known as caterpillars.

Owing to their brilliant colors, active habits and often also their large size, butterflies and moths are familiar objects to even the least observing of us. It should be known that there are fully as many species which are not ordinarily seen as there are of those seen. Some fly only at night and seldom are attracted to lights, others are so small as to escape notice. It is not uncommon to find a housekeeper making frantic efforts to capture some large moth which has strayed into the dwelling. She believes this moth, or "miller" as she sometimes calls it, is the cause of moth-eaten woolens, but in reality the clothes moth is so small and retiring that probably she has never seen one.

The adult lepidopterans are usually divided into two main groups, the moth and the butterflies. Moths are active at dusk or when the light is dim and usually remain motionlessly hiding while the sun shines. Their antennæ are never enlarged at the tips and their wings, when not in flight, rest flat on the back or meet on the back and slope to the sides like a roof. Butterflies are

active in sunlight, their antennæ are enlarged at the tips and their wings are held vertically above the body. The larvæ of the two groups cannot be so readily distinguished, as they have about the same forms and habits. Most of the larvæ eat plants, and usually each species eats a particular part of certain plants such as the wood of peach, the fruit of apples, the leaves of tomato and tobacco. The larvæ of some are hairy while others are bare or sparsely clothed. A few are slug-like in form but most of them are elongate-cylindrical, worm-like, but shorter than an earthworm. In addition to the three pairs of jointed tapering legs of the thorax, the lepidopterous larvæ usually have some blunt, unjointed prolegs under the abdomen. The larvæ of some moths, when ready to transform into the moth stage, spin silken cocoons about their bodies and inside of these cocoons they transform. The cocoons of a few species of moths, principally the mulberry silk-worm, *Bombyx mori,* are used in great numbers to furnish our supply of real silk.

Although a few species of *Lepidoptera,* like the silk-worm, are useful to us, a great many more are pests. Some, such as armyworms, cutworms, borers and fruit-worms are pests of crops; others, as grain-moths and clothes-moths are pests of stored products. The following discussions of a few species will illustrate some of the diverse habits found within the order.

Butterflies

Example: **White Cabbage Butterfly** (*Pontia rapæ* Linn.). Family, *Pieridæ.*

The commonest butterfly seen in most parts of the country is a white one which flies over the fields and gardens, usually not higher than our heads. It flies ap-

parently aimlessly, stopping frequently for a moment to rest on some low plant, then going in a new direction. In all probability its flight is not so aimless as it seems and it is seeking plants belonging to the *Cruciferæ* family such as cabbage, rape, turnip, mustard, nasturtium, cauliflower, horse-radish, radish, kale, etc. It is upon the leaves of

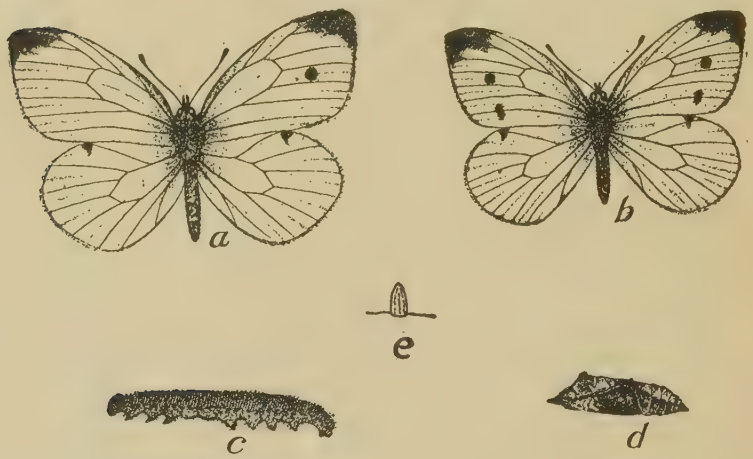


FIG. 83.—White cabbage butterfly. *a*, male; *b*, female; *c*, larva; *d*, pupa; *e*, egg. (Modified from Rumsey and Brooks.)

these plants that the larvæ live, so the butterfly must place the eggs there. How she can distinguish the plants of this family we do not know, but if a bit of the oil extracted from mustard plants be placed on other plants it will attract her, so it seems probable that a keen sense of smell guides her to the proper plants. She spends much time in locating places for her young to live. She is not content to deposit her eggs in large groups all in one place like many butterflies do, but instead she deposits a single egg in each place and thus her young may

occur in 200 or more different locations. An enemy must therefore look far and wide to find them, and some of them will surely survive. She may deposit a few eggs on different leaves of the same plant but the finding of a dozen or more larvæ on a plant is more often due to several butterflies having visited the same plant.

The larva is our common green cabbage caterpillar with which every gardener is familiar. It is so nearly the color of the cabbage leaf that we usually discover its presence by the holes it chews and the green pellets it drops among the leaves rather than by seeing the caterpillar. Its color and stationary habits probably protect it also from the sight of hungry birds and other enemies. It is inactive, remaining quietly feeding on the tender parts of the leaves of one plant usually during the entire larval period.

The butterfly of *Pontia rapæ* Linn. has a dark, slender, hairy body and white wings tipped with black. The female has in addition to the black tip, two black spots on each fore wing, while the male has only one such spot. The colors of all butterflies and moths are located in the tiny scales which cover the wings and body. If these scales are removed the wing will be transparent like that of a fly or bee. Examine the colored surface of a butterfly with a lens and you will find that unless it has been rubbed until some of the color is gone, the appearance is much like a miniature shingled roof. The scales overlap in even rows like shingles. The wonderful iridescent coloring of some butterflies is due to corrugations of the scales reflecting different colors at different angles. Scales are attached like hairs, for they are but modified hairs, and like hairs of higher animals are useful as protection against weather and mechanical injury.

The body of the cabbage butterfly has numerous long hairs in addition to the scales. Hairs are especially numerous on the thorax and head. About all that can be seen of the head is a pair of long slender antennæ, a pair of large compound eyes and a pair of short hairy palpi extending forward between the eyes with a brown coiled beak beneath. Surrounding these structures is a mass of hairs. The beak is quite different in appearance from the beak of bugs and aphids. It is coiled up like a hose and put away when not in use. When using it, however, the butterfly straightens it out and sucks liquid food much like bugs do. What the butterflies eat is not known, but they may be seen drinking from puddles of stagnant water, from the remains of dead fish or other animals, and even frequenting the droppings of animals in the roads or fields. Possibly they get some food in solution from such sources. The period of life as a butterfly is quite short, however, and much of the food for use in this stage is probably stored up during the larval period.

A female has been observed to deposit all of her 238 eggs in five days; 125 were laid on the first day after mating, 75 on the second day, 37 on the third and fourth days, and 1 on the fifth day. Apparently her energy was about spent on the last day. When depositing an egg the female butterfly alights on a leaf near the edge and curves the abdomen under her until its tip touches the leaf surface. Then she presses the tip firmly against the leaf for a second and withdraws it leaving an egg standing on end fastened to the leaf. The egg is one-twenty-fifth inch long, light yellow and shaped like a bullet with its point directed outward from the leaf. Like those of most butterflies the egg shell is pressed into a pretty design of

ridges and depressions by the mother's ovary or oviduct before leaving her body.

The larva when ready to leave the egg shell tears it near the outer end. A slit is made large enough for the larva to grasp the edges with its jaws and then the egg shell is eaten away until an opening is made through which the larva can crawl out. As soon as outside the larva turns around and completely devours its egg shell. The process of breaking out and devouring its shell occupies the larva for a couple hours and then it turns upon the leaf of the host plant on which it rests. It soon eats out little areas of the green cells between veins and in a few days has eaten large holes in the leaf. The larva seems content to remain in one place feeding continually and is not disturbed when touched. When fully fed so that the skin becomes too tight the larva fastens itself to the leaf with a few threads of silk as a preparation for molting. Then the skin splits along the anterior part of the back and the larva after considerable writhing manages to force its head through the crack, drawing its body after. The larva molts five times during its growth.

The larva shows very little resemblance to the butterfly, its parent. It lives such a different life that a different form is necessary. It is of a long, cylindrical, worm-like form and is often popularly called the cabbage-worm. Another name which is applied to this form of larva and which has been accepted by entomologists is caterpillar (L. catta, cat; pilosus, hairy). The larvæ of all butterflies and moths are known as caterpillars whether they are hairy like a cat or not. The caterpillar has jaws which chew leaves as a grasshopper does. Its legs are of two kinds: first, the 3 pairs of jointed legs attached to the thorax; and second, 5 pairs of rather stiff unjointed

legs under the abdomen. The latter are temporary legs to prop up the long worm-like abdomen and they disappear before the adult is formed. These prop legs are called prolegs. They have tiny hooks on the ends which may be used in clinging to objects. Four pairs of prolegs are under the middle of the body attached to segments 3, 4, 5 and 6 of the abdomen. The fifth pair is at the rear end of the creature. Thus he is supported fore, middle and rear. For eyes the caterpillar has six tiny simple ones scattered around the lower portion of each cheek. No compound eyes are present until the adult stage is reached.

The green cabbage caterpillars when full grown are about 1¼ inches long and when this state is reached they become restless. They crawl about until a place favorable for undergoing the next stage in life is found. They are obeying an urgent instinct to attach themselves to some permanent shelter where they may complete their transformation into butterflies. Many find fences, buildings, trees or stones to ascend and others, probably feeling that they must transform very quickly, remain on the stalks or under leaves of the cabbage plant without seeking other shelter. Each caterpillar attaches itself in a horizontal position beneath some supporting object by spinning silken threads from glands which supply the silk in a liquid form to the under lip where the silk hardens on exposure to the air. By applying the under lip to a surface the silk is attached, then by moving the head away a thread is drawn out from the place of attachment and may be continued until the lip is again applied to the surface to attach the other end of the thread. In this way some species of caterpillars spin silken cocoons but the cabbage caterpillar and other butterfly larvæ

spin only a few threads for holding the body in position during transformation. A mass of threads is attached to form a small pad in which the rear end of the body is then entangled. Having attached the rear end securely the larva next reaches its head around to spin a few threads about the middle of its body forming a loose belt around itself attached to the support above. Its position thus secured, the caterpillar remains quietly waiting for a time during which the body becomes shorter and thicker. Then the skin splits down the back and the insect gradually wriggles the old skin back toward the end of the abdomen, uncovering a pale soft creature unlike the caterpillar and unlike the butterfly. The stage now reached is the pupal or resting stage and is known as a pupa. Its skin soon hardens and takes on a greenish color. The shape is pointed and angular with none of the rounded, segmented appearance of the larva except on the abdomen. The pupa takes no food and makes no movement which is visible externally, but things are moving inside. The digestive system must be made over from the type that digests solid food to the type which digests liquid food. The nervous system is made over; the muscles must be made over to permit flying instead of crawling; the reproductive system must grow to maturity, and the wings must grow. The blood is very busy, carrying the materials from one place to another within the body, breaking down the fat stored by the larva to be built up into muscle, etc.

The development of some of the adult structures such as wings and reproductive organs was begun in the larva before it became full grown. As in the young grasshopper and bugs the wings were forming in pads attached to the upper side of the thorax, but in the cater-

pillars these pads are inside the body wall instead of outside. Therefore an observer is unaware of their growth until the shedding of the last larval skin discovers them. A close examination of the pupa reveals the large wings of the butterfly folded against the breast beneath the outer shell and between the wings are its long antennæ and legs. For the completion of that part of the transformation which takes place after the larval period, it requires about 10 days in warm summer weather and much longer in cool weather. When transformation is completed the butterfly bursts the pupal skin, draws out its body, unfolds its wings, and after the surface is hardened flies away.

A definite pupal form, different from the form of larva or adult, is found in the life cycles of all butterflies, moths, beetles, flies, bees, wasps and ants. These insects therefore have four distinct stages in their development—egg, larva, pupa, adult—and they are said to have a complete metamorphosis. The grasshoppers and bugs on the other hand have but three stages—egg, larva, adult—and they are said to have incomplete metamorphosis. Insects with complete metamorphosis form their wings inside the body while insects with incomplete metamorphosis form their wings outside in visible pads.

If we follow the stages of our cabbage butterfly through a year it will be found to proceed in the Northern states about as follows. Winter is spent as a pupa attached to an old cabbage stump or to the bottom of a fence board or the clapboards of a building. The butterfly emerges after the thermometer has reached a maximum of 60° for a few days in spring, usually in April. Males and females mate and the females seek early cruciferous plants

such as wild mustard or shepherd's purse on which to deposit the eggs. These hatch in a week or 10 days. The larvæ feed on the leaves for about four weeks then wander to solid objects to pupate. After two weeks of transformation the butterflies emerge from the pupal skin. This generation of butterflies is usually found flying over the fields in July. At this time they find cabbage, cauliflower, nasturtiums, rape, etc., on which to lay eggs for the second generation. These eggs hatch in 4 or 5 days now that the weather is warmer and the larva becomes full grown in 2 or 3 weeks. Then the transformation requires about 10 days and the second brood of butterflies emerges in August. These soon lay eggs on cabbage and other *Cruciferæ*. The larvæ of this third generation develop more slowly as the nights become cooler in late August and September, and when full grown in September they choose a sheltered place in which to spend the winter as pupæ.

In the extreme Southern states growth of the insects continues all year and there are 6 generations instead of 3. *Pontia rapæ* Linn. is found throughout this country and in Europe as well. Old residents can recall the time when it was not present in America. Written accounts of its damage to cabbage show that it was first noticed in Quebec in the year 1860. By 1865 it was found in Vermont and in 1869 near New York. In 1873 it was observed in Ohio and at Chicago in 1875. It was well established in Iowa and Missouri in 1878, in Montana by 1884 and southern California in 1896. Thus in 36 years after its entrance into America it had established itself throughout the country. Many foreign insects are accidentally shipped into our country on produce and gradually spread from year to year without being so readily

observed as this species was. Every gardener became readily aware of the damage to his cabbage and found the larvæ so easily that entomologists had no trouble in tracing the cabbage caterpillar, or Imported Cabbage-worm as it is sometimes called.

REFERENCES:
Wisconsin Agr. Exp. Sta., Research Bul. 45, 1919.
Manual of Vegetable Garden Insects, Crosby & Leonard, 1918.
Conn. Agr. Exp. Sta. Bul. 190, 1916.

Many of the close relatives of the cabbage butterfly are bright yellow butterflies such as the yellow ones with black markings which we see in large numbers near clover and alfalfa fields, where the larvæ live upon these plants. We see occasionally the larger yellow and black butterflies whose hind wings are extended out to a point, suggesting the name, "swallow-tail butterflies." In the larval stage they feed upon the leaves of various trees and shrubs. We see numerous brown butterflies of various shapes and sizes and frequently the dainty little blue and violet ones are quite common in field and roadside; but it would be necessary to go into tropical regions to find the great majority of butterflies. There the species are more abundant and the colors are often more brilliant. Among the most beautiful of colors in all nature are the iridescent shades of blue found on the *Morpho* butterflies of South America.

The butterflies are but a small portion of the entire order *Lepidoptera.* There are far more different kinds of moths and many more are commonly around us, but their nocturnal habits prevent us from observing them like we do the butterflies, unless we make an effort to find them.

The family **Hesperiidæ**, the "skippers," is intermediate between butterflies and moths. The adults are stout bodied moth-like insects, but their antennæ are enlarged at the tips and they fly by day as butterflies do.

FIG. 84.—A skipper. (From Comstock.)

FIG. 85.—Larva of a skipper. (From Comstock.)

The flight is short skips from plant to plant, and not like the slow, graceful flight of butterflies. The larvæ of skippers are caterpillars with narrow necks (Fig. 85) and they feed upon the leaves of plants which they often tie together with silk.

MOTHS

Example 1. **The Variegated Cutworm** (*Peridroma margaritosa* Haw.). Family, *Noctuidæ*.

To walk into your garden of a morning and find that some of the tender plants have been eaten off or cut down during the night is not an uncommon occurrence. The cause of such damage is often a mystery. Sometimes a rabbit is blamed for it, but sometimes a gardener with an investigating type of mind digs around the plants to learn whether there is a culprit hidden close by. If the soil is loose he may find near some of the plants a smooth, wormlike larva curled up among the soil particles beneath the surface. If the soil is muddy or hard the larva is probably curled up beneath a fallen leaf or in a crevice or

under whatever shelter occurs near the plants. This larva belongs to one of a large number of species all known as "cutworms." One of the most common species is the Variegated Cutworm.

It is distinguished from many other cutworms by its variegated colors. The back is dark with a row of yel-

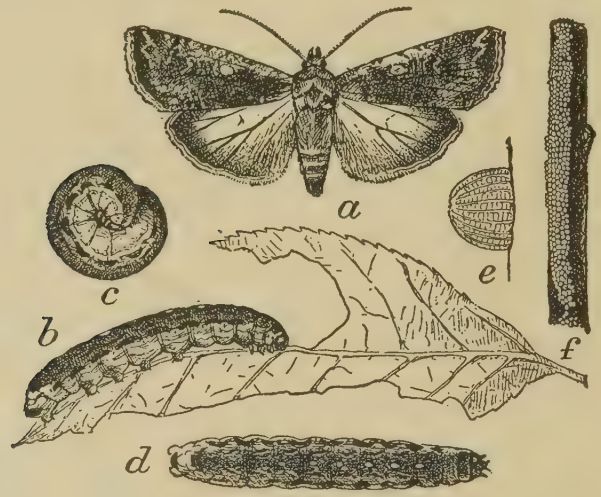


FIG. 86.—Variegated cutworm; *a*, moth; *b*, caterpillar on leaf; *c*, same in curved position; *d*, dark form, view of back; *e*, enlarged egg seen from side; *f*, egg mass on twig. (From Howard, U.S.D.A.)

low spots along the central line on some of the segments. At the lower edge of the dark area is a row of black dashes below which is a conspicuous yellowish band extending along the side. Beneath this band the body is lighter than on the back. The back and the lower side are variously mottled on different individuals, but the characters just given seem to be constant and are useful in distinguishing this species. When full grown the larva is nearly two inches long and quite plump.

The variegated cutworms normally hide by day and prowl about in the dark of night or during cloudy weather. During periods in which the temperature falls below about 60°, early in the evenings and stays low excepting when the sun shines, hunger drives the larvæ to forsake their nocturnal habits temporarily and feed by day. They are much less particular about their food than most plant eating insects and have been known to eat the succulent parts of almost every kind of weed or cultivated plant except poppies and various cucurbits, such as cucumber and squash. These they seem to avoid. Reports of their habits show that the variegated cutworms are not content with cutting off the stems of plants at the surface of the soil like many cutworms but have such varied habits as eating the leaves of young corn, eating holes into the sides of tomato fruit, climbing fruit trees to eat the leaves and fruit, eating peas out of the pods, and boring holes into the sides of carnation buds in greenhouses. Their presence about cultivated plants is more often noticed but the larvæ are most abundant on uncultivated areas where weeds or meadows are growing year after year. These offer more plants per square foot continually than cultivated areas, and the loss of plants here is not noticed. Occasionally a season especially favorable for their growth allows the cutworms to become so numerous that they destroy all the plants near them and then move in masses to find more food. They invade fields, gardens and orchards to eat whatever plants may be found in their path. When thus driven on by hunger they will feed night and day.

The larva when fully grown becomes more sluggish, and begins to shrink in size and when touched it switches the abdomen from side to side like a pupa. At this time

it enters the soil to a depth of about two inches and constructs a roomy cell with smooth packed walls in which to pupate. When the last larval skin is shed it uncovers a tan, oval pupa about an inch long, showing the segmentation of the abdomen and some indication of wings and legs beneath the shell. The pupa is pointed at the abdominal end. It grows gradually darker in color until it is almost black by the time that the moth is fully formed within. When the transformation within the pupal shell is completed, the pupa, by curling its abdomen and pushing, gradually works its way up to the surface so that its anterior half is exposed above the soil. In doing this it is aided by a pair of tiny hooks on the abdominal end of the pupal shell. After coming to rest with its head above soil the moth swells its anterior part and splits the pupal shell from which it then wriggles free. After the wings have expanded and dried, the moth comes to rest on some upright surface such as a cornstalk, fence, tree or stone.

The moth of the Variegated Cutworm is medium sized and quite sombre in coloring. Sometimes it is brownish gray and in other specimens it is dull purplish brown but in all it is mottled with wavy lines of lighter shade. The hind wings are lighter in color than the front wings. These moths, when the wings are expanded as shown in the figure are from an inch and a half to nearly two inches in width. They fly by night, and by day they remain motionless upon the surface of some tree or fence with the wings held down tightly over the back. The colors of the upper wings, head and thorax are usually so nearly the color of the dark surfaces on which they rest that one seldom observes the moth unless it is accidentally touched and thus caused to fly to another dark ob-

ject. By night the moths seek their mates and are said to drink the nectar from flowers for food. Their big compound eyes shine in the dark and because of this luminescence they are called owlet moths.

About the third night after leaving the pupal shell the female moths lay their eggs in large masses on the leaves of plants or other objects. Some moths are very careless about placing the eggs, for masses are often found on windows, walls of buildings, or even on lace curtains within a house. Such moths are probably attracted to lights where they become confused and deposit the eggs on the nearest available surface. A moth may lay up to 500 eggs in a mass and some deposit two masses of eggs. The moths have been kept alive as long as 13 days in summer but it is probable that most of them are destroyed much sooner either by battering their bodies against objects near lights or by storms or birds.

Each egg in the mass is at first a pale yellow hemisphere about 1/25 inch in diameter with many corrugations radiating from the pole. Soon the color darkens to brown as the embryo grows within. In a few days the larva eats his way out in much the same manner as the young cabbage caterpillar. After devouring their egg shells the Variegated Cutworms from an egg mass live in company until the first molt on the leaves of the plant where the eggs were laid. In this stage their habits are very unlike the habits of older larvæ. They do not attempt to hide by day and they move about with a looping gait like the "measuring-worms," for the prolegs which later support the middle of the body are not yet developed. The first stage larvæ are also different in color from the older ones. The color of the body is pale yellowish green with the lines very indistinctly marked; the

head is black. After the first molt which takes place in about a week they drop from the leaves to assume the cutworm habits of crawling and of hiding by day.

In tracing the life history of the species through a whole year we find that the habits are not uniform in the Variegated Cutworm. In Canada there are two generations each year and the winter is usually passed in either larval or pupal stages. Those larvæ which are able to become full grown before freezing weather change into pupæ while those caught partly grown by the low temperatures remain in that condition curled up in the soil until warmer weather permits them to complete the larval period in spring. In Kansas there are three generations completed each year and the winter is usually passed in the moth stage, the moths remaining hidden away in sheltered crevices all winter. In any locality it seems probable that the species can live through the winter as either moth, larva or pupa; the hibernating stage depending on the stage reached by each individual when low temperature stops its development.

The species is known to exist in most of the continents of the world and is supposed to have been shipped accidentally into America from Europe.

REFERENCES:

WADLEY, F. M. *Jour. Econ. Ent.*, Vol. 14, p. 272, 1921.

GIBSON, ARTHUR. Canada Dept. Agr., Entomol. Branch, Bul. 10, 1915.

MOTHS

Example 2. **The Spring Cankerworm** (*Paleacrita vernata* Peck). Family, *Geometridæ*.

While walking beneath the trees in May most of us have found dark greenish-gray caterpillars an inch or less

FIG. 87.—Cankerworms suspended by silken threads.

in length, dangling in the air, hanging by a thread. If you stop to watch one of them closely you may witness a gymnastic exhibition of rope climbing. Bending his head to one side and grasping the silken thread with the front legs and jaws, he lifts up his body far enough to loop the thread about the third pair of legs. He repeats this action again and again until the entire thread by which he hung from the branch above has been wound about his legs and he has regained the branch. Then he breaks off the thread from the coil about the third legs, and stepping out of the coil, walks away. Can you think of a sailor as able to climb a rope and while climbing coil up the loose rope below him? This caterpillar is not only able to coil his thread while climbing it but he can also manufacture his thread while descending it. He can start from a branch with one inch of thread and add to the lower end of that thread liquid silk from his mouth then drop until the liquid stiffens and checks his fall, then add more liquid silk and drop again, repeating this until he finds himself 15 feet or more below the branch.

The Spring Cankerworms, as these dangling larvæ are called, devour the leaves of apple, elm, hackberry, plum, cherry and numerous other trees and shrubs. When cankerworms are exceedingly numerous, as they are in some years, the leaves of many trees may be so completely eaten that only the petioles and bases of the veins remain attached to the twigs to show that leaves were present. If present in average numbers the larvæ eat their fill without seriously injuring the trees. They do not congregate in flocks but each larva lives independently and cuts a few holes through the leaf on which it feeds. The result of their feeding in average years is a general

appearance of small scattered holes, through the foliage of the tree. This is especially noticeable on the elms in parks and woodlands where it looks as though some ærial gunner had perforated the foliage with fine shot.

If we watch the Spring Cankerworms through a year

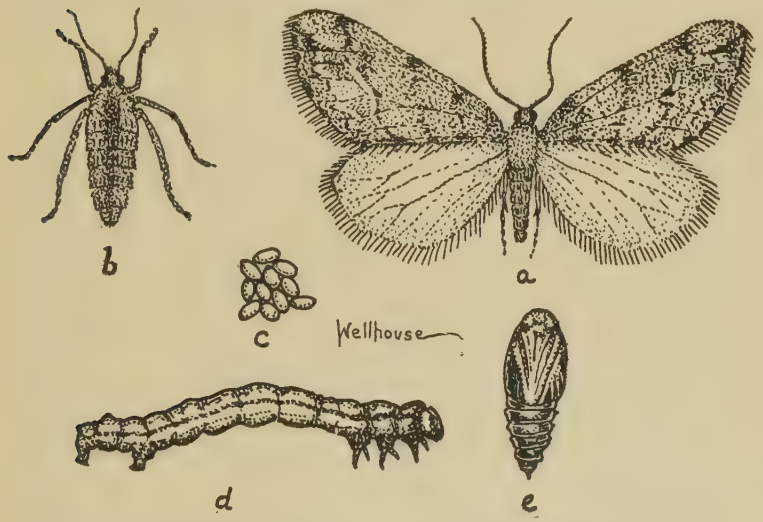


Fig. 88.—The spring cankerworm; *a*, male moth; *b*, female moth; *c*, eggs; *d*, larva; *e*, pupa.

of their existence we find that their periods of active life are short and that the greater part of the year is spent in confinement in cells below the surface of the ground. The larvæ dig their way into the soil an inch or so as soon as their growth is complete. The time of their disappearance from the trees varies with the temperature of the spring months. If the spring months are warm the larvæ disappear in May, while in localities where the springs are cold, as in our Northern states, they leave the

trees in June. They remain in the ground during the summer, autumn and winter,—three-quarters of the year. During the summer and early autumn the larvæ transform slowly into moths. Then the moth must remain within the pupal shell until after the freezing weather of winter has been felt. When the first warm nights of early spring arrive and the ground remains unfrozen for a night or two, usually in March and April, the moths break out of their shells and wriggle upward from the cells to the surface of the ground. There they await the dusk of evening before rising above the soil. Meanwhile the chitinous surface of their bodies is dried and the wings are expanded ready for flight.

The female cankerworm moths have no wings and consequently do not look like moths unless one examines the body to find it covered with the regular rows of overlapping scales like those of other Lepidoptera. The males are winged. Both sexes are gray or brownish-gray in color and are armed with rows of red spines across the top of the abdomen. These spines all point backward and assist the moths in wriggling upward through the soil.

After the sun has set the moths begin to leave the ground; the females climb upward on the nearest tree or post, and the males flutter about in the air until their mates are found. There are more males than females, sometimes in the proportion of three to one. Many of the males are attracted to lights and never find mates. The males of this species commonly enter our rooms during the first warm spring evenings before the windows are screened and are found fluttering against light globes. The females after mating rest on the tree trunks and hide

between the ridges of bark or in crevices during daylight. If the weather continues warm the females may begin to deposit eggs on the second night or if cool nights return they remain hiding until warmer weather before depositing eggs.

The eggs are laid in irregularities of the bark in masses of 50 or more and are glued together by a secretion from the oviducts of the mother. Each egg is but 1/25 inch long and opalescent in appearance. Development of the embryo within the egg is very dependent on temperature and the egg stage may vary from twenty to thirty-five days. The young cankerworm upon hatching does not completely devour its egg shell but eats only enough of the shell to make an exit. Then the larva begins to climb upward in search of leaves. Unless the mother has made the mistake of climbing a telephone pole, fence post or unsuitable kind of tree on which to deposit the eggs, the larva soon finds its proper food and proceeds to cut tiny holes between the veins of the leaf.

After having fed for a short time the silk glands begin to function and the larva then keeps a line of silk attached from its lower lip to the leaf surface. In case the wind dislodges it the larva falls only the length of its silken life line. Although its parents are active only at night, the larva is active only by day and likes sunlight. Rains drive the larvæ to the underside of their leaves and violent rains accompanied by wind shake them from the trees so that large numbers perish on the ground. They do not anchor their feet so securely to the leaves as most caterpillars do because the cankerworms do not have the normal number of feet. The prolegs beneath the central part of the body are missing and the rows

of tiny hooks on the ends of them are useful anchors to caterpillars which possess these prolegs. It is because of the lack of central legs also that the cankerworms must walk with a looping gait and are known as measuring-worms.

Birds are very fond of a cankerworm diet for they are not clothed with distasteful hairs and remain exposed on the surface of the trees where birds can readily find them. The cankerworms have a protective instinct which often saves them from birds, however. This is the habit of resting often in a stiff, straight posture extending at an angle of 45 degrees from the twig, holding on by the rear prolegs. The anterior part of the body stands out in the air supported by the almost invisible line of silk attached from mouth to twig. In this position they so resemble a branch of the twig that they often escape detection. Those larvæ which manage to escape their enemies become full grown in about a month and enter the soil, digging a tunnel with their jaws as they go. When firm soil is encountered they form cells in which they change to pupa within a few days.

The Spring Cankerworm lives nine to ten months as a pupa, a few days as an adult, about a month in the egg, and about a month as a larva. The larva during that month stores up food to last through the remainder of its life. The adults of this species have no mouthparts with which to take food and they die within a few days after giving up their sperms or eggs.

REFERENCES:

WELLHOUSE, W. H. Kans. Univ. Bul., Biol. Series, Vol. XVIII, pp. 281-324, 1917.

RILEY, C. V. Third Report U. S. Ent. Com., pp. 157-197, 1883.

PORTER, B. A., and ALDEN, C. H. U. S. D. A. Bul. 1238, 1924.

MOTHS

Example 3. **The Squash-vine Borer** (*Melittia satyriniformis* Hubn.). Family, *Ægeriidæ*.

Winter squash vines commonly wilt down suddenly in July or August after having made a fine healthy growth during the early part of the season. A close examination reveals no external signs of the trouble maker except small piles of wet, yellow "sawdust" which have been pushed out from small holes in the stems of the plant. The "sawdust" is really the excrement of a plump, white larva which lives within the hollow stems and eats the succulent tissues that form the tubular walls about it. After it has eaten nearly through the stem the supply of sap to the leaves is cut off and wilting results. The larva cuts a few small holes entirely through the wall of the stem, probably to get a change of air and to push out the excrement from its tunnel, thus improving the sanitation of its home. Possibly the holes also allow enough leakage of sap to prevent flooding of the tunnel with sap and thus insure the larva against drowning. This insect is known as the Squash-vine Borer. It seems to be more commonly destructive to late squashes than to other plants but it can live in all kinds of squash, pumpkin, melon or other vines of the family *Cucurbitaceæ*.

If we follow the Squash-vine Borer through a year in the northern United States, its life history will be about as follows: When the larva has completed its growth in August it bores out from the stem where it has spent its life and migrates to the soil nearby. Digging down like the cankerworm it forms a cell in which to transform beneath the surface of the ground. Unlike the canker-

worm, however, this larva has saved its silk supply until the end of the larval period and now uses it to weave a cocoon about its body. The cocoon is a dark colored, tough, waterproof wall composed more of a mixture of solid masses of silk with earth particles than of threads. It is about an inch long and oval in shape. Within this the larva spends the autumn and winter awaiting the

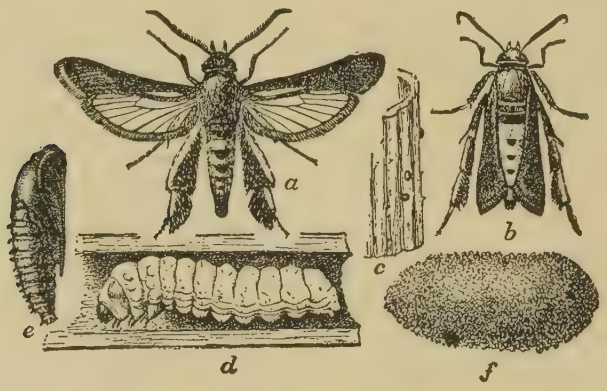


FIG. 89.—The Squash-vine borer: *a*, male moth; *b*, female, with wings at rest; *c*, eggs on bit of squash stem; *d*, full grown larva in vine; *e*, pupa; *f*, pupal cell. (From Chittenden, U.S.D.A.)

transformation into a moth. When the earth warms up in the spring the pupa is formed. After a few weeks in which the transformation is completed within the pupal skin, the pupa, by means of a horn-like appendage on the head, cuts the cocoon and wriggles up to the surface of the soil. Here the pupa rests with the anterior half of its body above ground and the abdomen still in the soil. The moth within soon bursts the pupal skin and emerges. When the wings are unfolded and the surface dried we find a strikingly beautiful moth, about ¾ inch long. The narrow fore wings are a lustrous black and the

wide hind wings are clear and transparent, although crossed by veins like the wing of a fly or wasp. The abdomen is marked with red or orange scales and the long hind legs are decorated with tufts of orange, black and white hairs. Because of the transparent wing areas, moths of the family *Ægeriidæ* are called "clear-wing" moths.

The moths dart about the fields and gardens in the heat of day and are readily mistaken for wasps. Early in the day and in the evening when most other moths are just beginning to fly, the squash-vine moths are sluggish, and rest on the leaves of plants where they may often be caught by hand. The female is capable of laying about 200 eggs. These are reddish brown ovals, flattened on top and bottom, and are smaller than a pinhead. They are laid only one at a place and usually on the main stems of the host plants near the ground. Sometimes they may be placed on the leaf-stalks or even on the undersides of the leaves. The moths deposit them as they pause while darting about in the sunshine.

In 10 to 15 days after the egg is laid, a tiny, white caterpillar, with black head, hatches from it, and at once begins to chew its way into the hollow interior of the vine. The larval growth period in the vine is about a month long in the Northern states. Farther south these stages require a shorter time for development and a second generation is completed each year. The larvae of the Squash-vine Borer and other boring *Lepidoptera* lack the prolegs under the abdomen, which other caterpillars have. Boring larvæ also lack the deep colors of insects which live in the open air and are white or creamy in color, sometimes with black markings where the chitin is thick.

REFERENCES:

CROSBY and LEONARD. *Manual of Vegetable Garden Insects*, p. 124, 1918.

WORTHLEY, HARLAN N. Mass. Agr. Col. Ext. Leaflet 44, 1922.

CHITTENDEN, F. H. U. S. Farmers' Bul. 668, 1915.

MOTHS

Example 4. The Fruit-tree Leaf-roller (*Cacœcia argyrospila* Walk.). Family, *Tortricidæ*.

If the foliage of an apple tree is examined in early June one can usually find some leaves on the tree which have been webbed together with silk or single leaves which have an edge rolled over and tied down to the central part of the leaf. Open one of these rolled leaves quickly and if the inhabitant has not deserted its home already, a very active green caterpillar with shining black head will run out from the end of the roll to drop from the leaf and hang suspended in the air like a cankerworm. He has an opening at each end of the roll and as soon as he becomes aware of your approach at either end he seeks to escape at the opposite end. He can run backward as easily as forward. The caterpillar belongs to one of a number of species known as leaf-rollers. One of the most commonly found species of the leaf-rollers is *Cacœcia argyrospila* Walk., known as the Fruit-tree Leaf-roller and a pest of the orchardists in some regions where it is especially abundant. An account of this species as observed and written by Bentley B. Fulton follows:

FIG. 90.—Fruit-tree leaf-roller moth. (From Fulton.)

"The fruit-tree leaf-roller spends more than nine

months of its life as an egg attached to the bark of the tree. The eggs are deposited in oval masses from one-eighth to nearly one-fourth of an inch long, made up of from ten to eighty eggs, averaging about forty or fifty.

"The individual eggs are rather flattened and overlap each other like the scales on a fish. A substance secreted

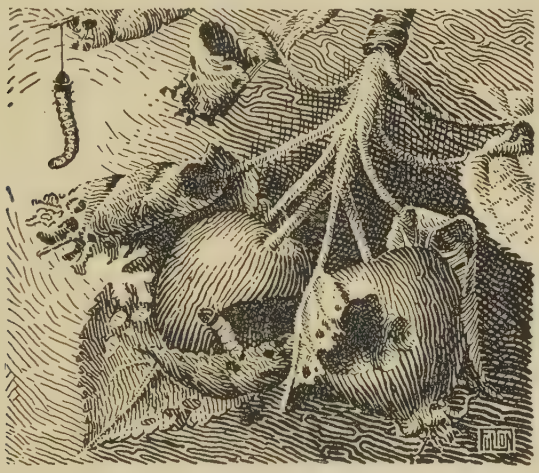


Fig. 91.—Work of larvæ on leaves and fruit. (From Fulton.)

by the moth, at the time of oviposition, hardens and forms a coating which partially obscures the composite character of the egg cluster.

"When first deposited, the egg masses are greenish, later turning brown, and are not easily observed. After passing the winter on the tree, most of them retain their brown color, but others become pale brown or even whitish. Some of the clusters seem to dry out, during certain years at least, and part or all of the eggs in these clusters fail to hatch even when not touched by a spray.

Hatched egg masses generally acquire a bleached whitish color and may remain on the trees through several seasons.

"No part of the tree can be said to be free from eggs, although the majority of them are on branches from one-half to two inches in diameter. They may be found on the trunk and main branches and are quite plentiful even on the small terminal twigs, a place which is easily missed when spraying. There is a tendency on the part of the moths to place the eggs at the base of a spur or branch or alongside of some previously deposited egg mass. Clusters of four or five partly overlapping are fairly common. Often the egg masses of two or three seasons are grouped together.

FIG. 92. — Leaf-roller eggs, upper two masses unhatched; lower two hatched. (From Fulton.)

"The eggs began hatching in the Imbler district in 1920 at the time the trees were in what we call the cluster bud stage, and hatching was not entirely completed until the blossoms showed pink on the majority of trees. The young caterpillar within the egg chews an oval or roughly semi-circular hole through the upper side of the egg and protective coating, through which it crawls to liberty. The process of chewing the hole requires over an hour for completion; those observed took that long after the hole was already of good size. If a spray could be devised that would leave a hardened deposit over the egg mass it might be of value in preventing the hatching.

"The newly hatched leaf-roller is pale yellow with a

shiny black head. On leaving the egg it crawls away to explore, and investigates all hollows in the leaves or floral parts, seeking one that is sufficiently enclosed to suit its needs. It then proceeds to spin a silken web further to confine the space, leaving only enough of an outlet to satisfy its present needs for food. The extreme woolliness of many of the growing parts of apple buds, makes feeding on these parts difficult for so delicate a larva, and it is perhaps for this reason that so many of the young leaf-rollers find their way to the blossoms before establishing a web. At any rate, the great majority pass the first few stages of their existence within the blossoms. The choice location is beneath the circle of stamens which they web together. Here they feed upon the calyx cup and parts of the stamens and pistils, and may injure or destroy these vital parts before the blossom is fertilized. They also web the petals together and feed upon them, so that many of the blossoms are unable to open when they otherwise would.

"After the larvæ have molted their skin two or three times, they are about half grown, and of a green color with a black head and thoracic shield. They feed on the leaves more extensively, and keep themselves entirely concealed, either by fastening two or more leaves together and living between them or by rolling up one side of a leaf and feeding within the cavity thus formed. All exposed places are covered with sheets of fine silken web, except that at either end of the nest avenues for feeding or escape are left open. When there is room on a tree for a choice of food, the young terminal leaves and the fruit spurs are attacked first. Large, irregular cavities are chewed in the sides of the fruit, to which a leaf is fastened to form the customary protection. Many of the

injured apples fall and those which remain become distorted and scarred.

"When the larvæ are disturbed sufficiently they wriggle backward out of the nest and drop, but remain suspended by a web spun from the mouth. After hanging for a time they laboriously climb back up to the leaf. This course of action is adopted when attacked by a parasitic insect. If the larvæ drop to the ground and land in the sunlight, their lot is a hard one. On cultivated ground they succumb after a few minutes' exposure to sunlight. If they alight in the shade they crawl toward the trunk of the tree. In this movement they are probably directed by the sense of sight, for they crawl toward any large, dark object.

"The full-grown leaf-roller caterpillars are about one inch in length. During an average season this size is attained after about one month from the time of hatching.

"The next step in the life-history is the transformation to a dark brown pupa. The pupa is fastened by a web within a rolled leaf and is entirely concealed. After a period of about two weeks, depending on the temperature, the pupa works its way out to the edge of the nest, by the aid of backward-pointing spines along the abdominal segments. The moth emerges, leaving the empty pupa case fastened to the leaf."

The moths are night flyers and remain quietly resting on the trees during the day. They mate and begin egg laying within a few days after leaving the pupal case. The females lay their eggs by night in one or two masses and die very shortly afterward. As individuals complete their growth and transformation quite unevenly, there may be moths found continuously during a month or more, in late June and July. The life of each moth is,

however, but a few days of that period. When at rest the moth holds its fore wings quite flat on the back with the hind wings entirely concealed beneath them. When in this position the moth is from one-third to one-half inch long. The typical color is reddish brown with dark brown and straw colored markings but some are entirely straw colored and others are entirely brown except for a silvery spot on the margin of each fore wing.

The Fruit-tree Leaf-roller is found all over the country and on many other kinds of trees besides apple. Nearly all the deciduous fruit trees except peach may be chosen by the moths as host plants and many forest trees are also infested, but apple seems to be their favorite host.

Several of the other species of leaf-rollers spend the winter as partly grown larvæ in silken tubes buried in the bark at the crotch where two twigs join together. The eggs of these species are laid in patches on the leaves. The larvæ of a few members of the family *Tortricidæ* hide within fruits instead of buds or rolled leaves. The codlin moth larva which causes so many wormy apples is an example of this group.

REFERENCES:

FULTON, B. B. 3rd Crop Pest and Horticultural Rept., Ore. Agr. Col. Exp. Sta., pp. 82-85, 1921.

REGAN, W. S. Mont. Agr. Exp. Sta. Bul. 154, 1923.

HERRICK, GLENN W., and LEIBY, R. W. Cornell Univ. Agr. Exp. Sta. Bul. 367, 1915.

MOTHS

Example 5. **The Apple Trumpet Leaf-miner** (*Tischeria malifoliella* Clem.). Family, *Tineidæ*.

The leaves of apple, wild crabapple and wild hawthorn trees are frequently disfigured by little brownish

patches on the upper surface. These patches are about one-half inch long and, beginning as a narrow line, they gradually widen out like the end of a trumpet (Fig. 93). The leaf surface over these areas is not broken and, if you turn the leaf over, you see no evidence of the discolored areas from the lower side which is uniformly green. If the brown upper surface is cut away, it will be seen that the green tissue just under the upper surface has disappeared, leaving a broad, flat cavity or mine.

FIG. 93.—Trumpet leaf mines. (From Fulton.)

The maker of this flat mine —so flat that it has not the thickness of a leaf—is a small, flattened, green larva about one-eighth inch long. It is so well adapted for living in this flat space that all appendages, such as legs, which would tend to increase its thickness, are absent. Even the prolegs, so characteristic of lepidopterous larvæ, are merely represented by the tiny hooklets which normally occur on their tips, and the brown head is quite flat, with its jaws pointed forward instead of downward.

The eggs of this leaf-miner are deposited here and there upon the upper surface of the leaves. They are tiny, oval yellowish eggs about one-fiftieth inch long, each being attached in the furrow over a veinlet. After an incubation period of from 8 to 12 days, varying with

the temperature, a tiny larva cuts its way through the bottom of the egg shell and into the leaf below, without exposing itself upon the leaf surface at all. Having gained the interior of the leaf the larva begins to eat the green tissue under the surface. It starts the mine by eating a straight tunnel slightly wider than itself. As it grows and its appetite increases, the larva reaches farther to each side for food and the mine is widened until it may be one-fourth inch or more across.

From the very beginning, the larva lines its mine with delicate strands of white silk. Soon after it begins to feed, the larva also cuts a tiny crescent-shaped slit through the floor of its mine, through which its excreta are pushed out, for the interior of its home must be kept clean. From time to time as the larva moves along into the larger portions of its mine, new crescent-shaped slits are made, for casting out the waste. The larva molts five times and becomes full grown in from 13 to 17 days in midsummer. Then it changes to a pupa, as it molts the fifth time, within the mine. After 6 to 12 days in the pupal stage, the moth is ready to emerge. Aided by the spines on its head and abdomen, the mature pupa tears a hole in the roof over its head and wriggles out until a portion of its body extends up through the hole. Then the skin is split and the moth emerges.

The moth is only about one-eighth inch long and its extended wings are not over three-eighths inch from tip to tip. It is a shining dark brown with a purplish lustre and has a very deep fringe about all margins of the wings, except the front of the fore wing (Fig. 94). These tiny moths spend the daylight hours sitting in the shadow among the leaves, where they are seldom seen. If disturbed by your close approach they will fly a short dis-

tance to other leaves during the day, but under normal conditions they are active only in the twilight and dark. They have the peculiar attitude of resting with the front end of the body extended out from the leaf as far as the front legs will reach, while the rear end of the body touches the leaf surface.

The moths are able to suck drops of honey dew or nectar and may live for two or three weeks. Mating usually occurs the first or second night after the emer-

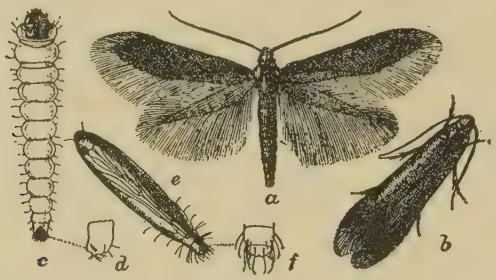


FIG. 94.—Apple-trumpet leaf-miner: *a, b,* adult moths; *c,* larva; *d,* last segment of larva, side view; *e,* pupa; *f,* last segment of pupa enlarged. (From Quaintance, U.S.D.A.)

gence of the females and Dunnam found that a male may mate with several females. The females begin laying eggs about two days after their emergence and continue for about a week. A total of approximately 50 eggs is deposited on the leaves by each one.

There are from 2 to 4 generations completed each year in various sections of the United States, the number being greatest in the south. In the latitude of central Iowa there are 3 generations, the moths appearing in early May, July and August. Larvæ of the third generation line their mines, in the autumn, with a dense, white wall

of silk and spend the winter there. The leaves fall upon the ground and thus gain added protection for the enclosed larvæ. Pupation takes place in April and the moths then emerge from the old leaves upon the ground.

REFERENCES:

DUNNAM, E. W. Iowa Agr. Exp. Sta. Bul., 1924.
QUAINTANCE, A. L. U. S. D. A. Bur. Ent. Bul. 68, p. 23, 1909.

The moths whose habits we have considered are types which represent the general habits of many other species, although each species differs in some respects from all the others. There are probably more than a thousand species of cutworms, for instance, and not one of them behaves exactly like the variegated cutworms in all respects. Some species of the cutworm group become exceedingly numerous occasionally and move like an army from field to field destroying crops as they go. Such species have been called "army worm," "wheat-head army worm," "army cutworm," etc., by the economic entomologists.

The spring cankerworm also represents but one of a host of measuring worms which occur on various trees and other plants; and the squash-vine borer is but one of a hundred or more clear-winged moths whose larvæ bore into plants. Likewise the apple trumpet leaf-miner is but one of a host of leaf-miners. Even the apple tree has its leaves mined by six or eight related species. Then, there are several species of clothes moths whose larvæ destroy our woollens; a number of meal moths whose larvæ render unfit for use our breakfast foods and dried fruits and nuts, or stop up the chutes in flour mills by their webs; the moths whose larvæ are apple worms, and

moths and more moths. We might fill the rest of this volume with an enumeration of the habits of moths and their larvæ.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology,* Chap. XXVII, 1924.
IMMS, A. D. *General Textbook of Entomology,* pp. 401-455, 1925.

CHAPTER XVII

ORDER TRICHOPTERA

(Trichos, hair; ptera, wings)

The members of this order have two pairs of membranous wings which are usually covered more or less densely with soft, clinging hairs. The general appearance of the body is moth-like. The mouthparts of adults are vestigial or absent, except a pair of prominent palpi. The larvæ are aquatic and resemble caterpillars.

Adults of *Trichoptera* are known as caddis-flies and are usually small, moth-like insects found on objects near streams, lakes and ponds, although they may be found about lights at night. The body is soft and covered with hairs, as are the wings also in most species. The hind wings are shorter and broader than the fore wings, and both pairs rest slanting like a roof over the abdomen. The caddis-flies range in size from less than one-eighth inch to more than one inch in length. If they take food it is taken at night and no one seems to have discovered any of them feeding. The jaws are so poorly developed that it seems doubtful whether food could be eaten. The only noticeable mouthparts are the slender palpi which extend out from below the head. Occasionally great numbers of them are attracted to city lights where the caddis-flies may become an annoyance, but otherwise no one but an entomologist would be apt to notice them as they rest on stones, trees, etc., near the water.

The eggs are laid in masses, either in water or upon

objects above water so that the larvæ can drop or crawl into the water. Some females that lay their eggs in the water, descend partly submerged stems or timbers until below the surface in order to cement their eggs there.

FIG. 95.—Caddis-fly.

The larvæ are usually caterpillar-like and live on the bottoms of streams, ponds, etc., where they often make cases of pebbles, sticks or silk in which to live protected somewhat from the jaws of larger predaceous insects and fish.

The larvæ are called caddis-worms. They have well-developed jaws and devour small animals, plants and bits of dead organic material which float within their reach. Each species makes a special kind of case in which to live and most of the cases can be dragged about from place to place by the larva within. In moving its case the larva extends its head and thorax outside through the open end and uses the thoracic legs to pull itself along. Some cases are made of grains of sand, some of coarse gravel, some of sticks piled log-cabin fashion, some of leaves which have fallen into the water, and others of silk alone. All are cemented together and lined with silk. One group of larvæ spins a funnel-shaped web with its open end up-stream to catch tiny organisms which come down in the current. The "catch" forms the food of the net builder.

FIG. 96.—Caddis-worm.

When fully grown the caddis-worm commonly forms a sort of screen door of silk over the open end of its case

and, thus shut in, it changes to a pupa. The door allows water to pass through so that the pupa will be continually bathed in fresh water for its respiration, yet intruders and silt are kept out. A few larvæ leave the open water to burrow into wood or soil for pupation. The emergence of the adult is different from that of most aquatic insects for others more commonly leave the water before the adult form is attained, while *Trichoptera* pupate below the water. The caddis-fly emerges from its case at the bottom of the stream and swims to the surface where it usually grasps some object upon which it can climb above the water to expand and dry its wings; in swift water some species are able to expand their wings instantly when they reach the surface and fly to some object above the water.

The order is a fairly large group of about 1,600 species, some of which are found in most all parts of the world. They are of no economic importance so far as we know, but their habits are but little known.

References:

Comstock, J. H. *Introduction to Entomology,* Chap. XXVI, 1924.
Lloyd, J. T. Lloyd Library Bul. 21, 1921.

CHAPTER XVIII

ORDER MECOPTERA

(Gr. mecos, length; ptera, wings)

The members of this order usually have two pairs of long, narrow, membranous, similar wings, with a moderate number of veins and often spotted with dark colors; wings are absent or vestigial in some species. The head is elongated into a beak which has the chewing jaws and palpi situated on the tip. The larvae are caterpillar-like in form.

Mecoptera is a small and little known order containing about 160 species of strange insects. The most constant feature of the order is the head; it is drawn out into a broad beak, at the tip of which the slender palpi may be readily seen. A complete set of sharp, chewing mouth-parts is located there, but the palpi are

FIG. 97.—Scorpion-fly. (From Kellogg.)

FIG. 98.—Larva of Scorpion-fly. (From Kellogg.)

more easily discovered than the other parts. One group of the order includes the scorpion-flies, so called, because the tip of the abdomen is bent upward and pointed like the sting of a scorpion. The scorpion-flies are, however, harmless and possess no sting. They are found resting on the

foliage of weeds growing in damp shady woods, and are probably nocturnal in habit. Their food seems to be largely dead or weakened insects and the fruit of the plants on which the scorpion-flies are found. The eggs are placed in crevices in the ground and the larvæ either burrow just beneath the surface or wander about on the surface of the ground hunting food. They are said to feed upon insects or other small animals. Pupation takes place in a cell in the soil.

Fig. 99.—*Bittacus.* (From Kellogg.)

Another group, called *Bittacus,* consists of long-legged, extremely slender-bodied, narrow-winged insects which do not resemble scorpion-flies except for the long beak. They live in the same situations as scorpion-flies, but are usually found hanging suspended by the front legs from some plant. Small insects coming within reach of the long legs are seized and eaten. It is said that the eggs are dropped on the ground at random, but almost nothing is known of the life history or habits.

Fig. 100.—*Boreus.*

A third group, called *Boreus,* consists of tiny leaping black insects which sometimes appear on snow. The wings are either absent or are mere rudiments. The female has an ovipositor nearly as long as the abdomen.

The larvæ resemble those of scorpion-flies and pupate in the ground. *Boreus* apparently feeds upon moss instead of insects.

REFERENCES:

COMSTOCK, J. H. *Introduction to Entomology*, Chap. XXV, 1924.
IMMS, A. D. *General Textbook of Entomology*, pp. 387-391, 1925.

CHAPTER XIX

ORDER DIPTERA

(Gr. di, two; ptera, wings)

The members of this order have only one pair of wings. These are usually transparent and traversed by a few long dark veins. No jaws for chewing are present but they usually possess a beak for sucking liquid food. The larvæ have no legs and travel very little; the majority lack a distinct head and are then called maggots.

The adult insects of this order are called flies, mosquitoes, midges and gnats. It should be remembered that Mayflies, stoneflies, butterflies, lacewing flies and some others having compound names containing the word "fly" are not members of this order and possess two pairs of wings, while the true flies possess one pair. Flies are generally good fliers and take flight quickly when approached. Some of the gnat swarms can use the wings to keep up a continuous dancing in the air for hours at a time, and some of the larger flies have the ability to hover in the air almost motionless except for the rapid beating of the wings. With the exception of mosquitoes, most *Diptera* are lovers of sunlight and rest at night clinging to objects. Flies are usually found about animals, flowers or filth. Their food consists of plant juices, animal blood or the nutritious liquid portions of decaying organic material. Flies are among the most commonly seen insects.

The larvæ of most *Diptera* live in water, in wet soil, inside of plants, animals or other objects where the body

may be kept moist. A few exceptional ones are able to maintain themselves in the open air on surfaces of plants. The lack of legs as well as the avoidance of sunlight tend to keep the larvæ from coming out into our sight. They are therefore not often seen although there may be hundreds of them near us.

Flies are of importance to us both from a medical and an agricultural standpoint. Some species carry serious diseases of man or his stock and some larvæ are themselves parasites in stock. Other larvæ destroy the young plants of our cultivated crops or cause "wormy" fruits on our trees. The appearance and habits of some of the groups of *Diptera* will be illustrated in the following examples.

Biters

Example 1. **The House Mosquito** (*Culex pipiens* Linn.). Family, *Culicidæ*.

Most of us need no introduction to those slight insects with a lean and hungry look, known as mosquitoes. We have experienced their bites and recognize the song which has become so suggestive that we prepare for the bite, upon hearing it. Among the many species of this family one of the most common is *Culex pipiens* Linn., the mosquito which lives near our houses, whether in towns or on farms. We think of periods following wet weather as times to expect mosquito bites because the larvæ must live in standing water. Larvæ develop in water collected in rain barrels, buckets, tin cans, watering troughs, puddles or hoofprints in ground where frequent showers or seepage keep them filled.

Wet grass and shrubbery are not breeding places for

mosquitoes unless puddles of water stand under them, but the adults hide in such places during the day and may readily be awakened from their rest when you brush against the plants to which they cling. To breed mosquitoes water must remain standing long enough for the egg, larval and pupal stages to be completed in it. This requires at least 10 days and if the puddle becomes dry in less time than that the mosquitoes in it die. If standing water is available they will continue to produce generation after generation all summer long, but if the water evaporates, only a few adult mosquitoes survive and they await the return of standing water in which to deposit eggs. Water which flows freely as in the channels of streams or which is open to the rippling effect of the wind does not allow the larvæ and pupæ to mature. This is due, probably, to interference with their breathing and food supply.

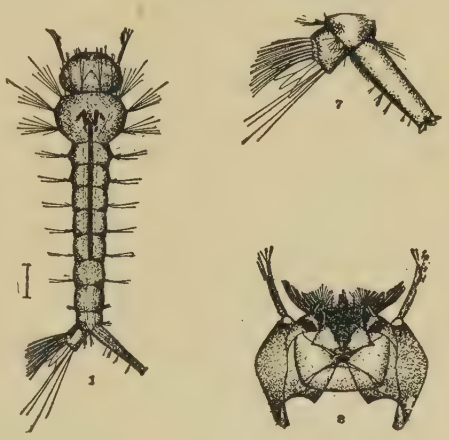


FIG. 101.—Larva of House Mosquito: 1, mature larva; 2, head from below showing hairs about mouth; 7, tip of abdomen enlarged to show breathing tube and gills. (From Headlee.)

The larvæ or "wigglers" rest much of the time with the tip of the abdomen at the surface of the water and the head hanging downward at an angle of about 45 degrees. Attached to the next to the last abdominal segment is a tube used in respiration. The tracheæ within the body

extend out through this tube and end at its tip in a pair of spiracles. Surrounding (Fig. 101) the spiracles are a number of small pointed flaps. The larva pushes the tube up through the surface of the water until the spiracles are exposed to atmospheric air, then bends down the flaps on top of the surface. The tension of the surface film supports the larva in this position while it rests and renews the air supply in the tracheæ. At the

FIG. 102.—Diagrammatic life history of House Mosquito: 1, egg; 2, newly hatched larvæ; 3, developed larvæ; 4, pupa; 5, adult. (From Headlee.)

end of the last segment of the abdomen surrounding the anal opening of the digestive system are four flaps and many hairs. The flaps are gills by means of which some oxygen can be secured under water but not enough to maintain life.

The wigglers leave the surface and wiggle their abdomens in such a way as to swim about through the water in search of food. They eat microscopic animals and plants which occur in stagnant water, or sometimes they eat their younger brothers when other food is not plentiful. Mosquito larvæ differ from ordinary maggots in having the head well developed and distinct from the

thorax. They have antennæ and well developed jaws for chewing the food but probably the most peculiar structures of the head are a pair of movable moustaches. These are useful in setting up currents of water which carry the food into the mouth and they remove the silt when their motion is reversed. In this respect they are substitutes for front legs which are commonly used to secure food and to clean the faces of the insects possessing them. After spending from five to ten days eating, breathing, growing and during that period molting the skin three times, the larva sheds its skin again.

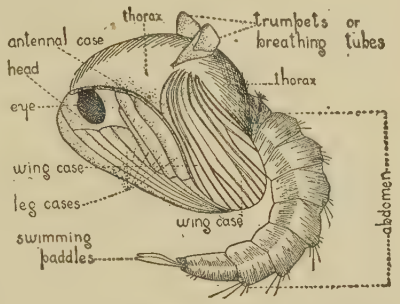


FIG. 103.—Mosquito pupa with parts named. (From Headlee.)

This time it uncovers the pupa, a creature shaped like a comma and much more active than most pupæ. They hang from the surface with a pair of trumpet-shaped respiratory tubes pushed up through the surface film into the air. The respiratory tubes are no longer attached to the rear end of the body but are outgrowths from the top of the thorax in this stage. Beneath the thorax may be seen the wings, legs and antennæ of the future mosquito, folded beneath the skin. At the tip of the abdomen the place of the larval gills has been taken by a pair of swimming paddles, and the pupa, when disturbed, can swim rapidly down into the water, carrying an air bubble in each air trumpet. No food can be taken in this stage but the mosquito form is being completed

within, using energy derived from food stored during the larval period. The pupal stage lasts but two or three days in warm weather, or a little longer if the weather is cool.

At the end of that stage, the adult splits the skin along the top of the thorax, which lies just beneath the surface of the water, and works its way out into the air to rest on the pupal skin a moment while its wings unfold and dry. Then it flies away to rest in the shade on plants or other objects. A sudden breeze rippling exposed water during the emergence period drowns the mosquitoes before they can fly. During any of the stages spent in the water, mosquitoes are also in danger of destruction by being eaten. They form part of the diet of many small fishes and carnivorous insects and mosquitoes seldom live in ponds where fish are present.

Adult mosquitoes are slender, long-legged insects that may be distinguished from other two-winged flies or gnats by the presence of a row of scales attached to the rear edge of the wing; and usually there are scales attached to some of the wing veins also. The scales can be seen with a hand lens. They are flat, thin structures, easily distinguished from hairs. Males have a pair of prominent antennæ, each appearing like an ostrich plume with long hairs arising in whorls from the sides of a central shaft. The females' antennæ have a few short hairs arising from the shaft. Experiments have shown that the hum of the female, which is the note "C" produced by 512 vibrations per second, causes the plumose antenna of the male to vibrate sympathetically. The eyesight of mosquitoes is not keen in the dark and they seem to depend upon sound and odor to direct them. The male probably turns his head until both of his antennæ are

equally affected by the hum of the female, then flying straight ahead he is able to locate her. The food of mos-

FIG. 104.—*Culex* mosquitoes; female above, abdomen swollen with blood; male below, details of scales on wing and feet. (From Howard, U.S.D.A.)

quitoes is probably located by the senses of smell and touch.

Males have such weak, flexible mouth parts that they are unable to pierce the skin of animals and apparently

they never try to do so but remain hidden among the vegetation and drink nectar or other plant juices easily obtained there. Females of some species drill into plants for their food but females of the better known species, such as the House Mosquito, drill into the skin of man and other animals for their food. For this purpose they have long, sharp beaks somewhat like those of the *Hemiptera* (page 20). Two of the long, slender stylets in the beak have saw-tooth edges and are used to saw through the cuticle of the host. Other needle-like stylets fit together so as to form two tiny canals within which the saliva and blood pass. Injection of the mosquito's saliva into the wound precedes the sucking of blood into the stomach. Unless disturbed, she will continue to feed until the abdomen is distended nearly to bursting. A full meal requires about three minutes, after which she flies away to rest until the blood is digested and hunger returns.

It is the blood hunger of female mosquitoes which makes them follow us and become such nuisances. They are of greatest importance to us, however, because of their disease carrying capacity. The House Mosquito, which is the subject of our discussion here, is not a disease carrier, but a number of other mosquitoes common in tropical regions and the warmer temperate regions such as our Southern states are known as malarial mosquitoes and yellow-fever mosquitoes because they carry those diseases. The microscopic organisms causing malarial fever and yellow fever live in the blood of persons having those diseases. When a mosquito bites such a person it takes the disease organisms into its stomach with the blood. In the proper kind of a mosquito the organisms continue to grow and get into the insect's saliva. If an-

other person is bitten then, the saliva carries the disease into the wound. Yellow fever is no longer prevalent in America and consequently very few mosquitoes get a chance to carry it, but malarial fevers are still the cause of much illness in the southern half of the United States and other warm regions of the world. These fevers cannot be acquired in any other way excepting through the bite of a mosquito carrying the disease.

The female House Mosquito after mating deposits her eggs in a mass of from 50 to 400 on the surface of the water. The egg mass floats like a tiny black raft made up of elongate, slender, black eggs standing on end and cemented together along the sides. About 24 hours after the mass is deposited tiny wigglers begin to emerge from the lower end of each egg into the water. The egg stage will be much longer in cool weather.

When winter comes the eggs, larvæ and pupæ in pools freeze up and die in the Northern states. The males and many of the female adults also perish in the cold weather, but a few fertilized females seem to live through each winter and lay eggs the next spring. They hide in protected places such as cracks and holes in trees, buildings, etc., where they remain dormant all winter.

References:

Headle, T. J. N. J. Agr. Exp. Sta. Bul. 348, 1921.

Howard, L. O. U. S. D. A., Div. Ent. Bul. 25, N. S. 1900.

Biters

Example 2. **The Big Black Horsefly** (*Tabanus atratus* Fab.). Family, *Tabanidæ*.

Any one who has watched horses or cattle is familiar with the big bluish black fly, about an inch long, which

occasionally settles on the animals to bite them. These flies are not so numerous as the smaller flies but their size makes them noticeable. There are several species of such flies but one of the most common in the Northern states is *Tabanus atratus* Fab. which we may call the Big Black Horsefly. Its body and even the wings are dull black. The body has a whitish powder over it which gives the insect a bluish cast. These insects are swift fliers and not easily captured except while they are feeding on the animals.

Among the horseflies, as among the mosquitoes, only the females do the biting. Males lack some of the needle-like piercers which are present in the mouthparts of the females, and are consequently unable to pierce the skin. Males are said to drink the sweet sap of tender plants and the nectar from flowers. Females may also use plant food at times but the habit of taking animal blood is quite general among them. The flies may be found from late May to October and they are most commonly found near swampy places but will sometimes fly miles away from swamps to find animals. They seem to have keen sight and that is not surprising when their eyes are examined. The large head is almost all eyes. The two compound eyes cover the entire sides of the head and in males they extend so far across the front of the head as to meet in the middle of the face. In females there is a short distance between them.

After mating has taken place, females deposit their eggs on sedges and grasses which are found growing in marshes. Occasionally the eggs may be placed on sticks projecting from the water. A female deposits her eggs in a mass of 100 or more. The eggs are cemented onto

the plant and to each other in regular rows and piled in four or five tiers, one tier on top of another. Each egg is elongate, brown, about one-tenth inch long, and stands on end. About one week after they are deposited the eggs of a mass hatch, all at about the same time, and the wig-

FIG. 105.—The Big Black Horsefly: *a*, larva; *b*, pupa; *c*, adult. (From Howard, after Riley.)

gling larvæ go tumbling down into the water together. Once in the water they separate and sink to the muddy bottom where they conceal themselves so securely that they are not usually seen again until they appear as adults.

The larvæ are at first transparent, shining white, but later they become conspicuously marked with irregular brown bands over the white. They are long and spindle shaped, tapering to a point at each end. The length of the full grown larva is about two inches. The front edge of each abdominal segment is encircled by a band of eight small tubercles which aid in crawling about through the mud. At the rear end of the body is a pair of spir-

acles which probably are not used until the larva burrows out into soil where the atmosphere penetrates between the particles of earth. Younger larvæ living in water or mud probably take their oxygen directly through the skin. Larvæ have jaws for chewing and their food consists of earthworms, snails, insects and even their own species. The young larvæ may be found in the mud and débris collected along the edges of pools and in swamps. As they grow larger the larvæ may burrow through the soil beyond the edges of the water in search of earthworms and insect larvæ for food. They are very active and muscular creatures with a firm shining surface. When freezing weather arrives they become dormant in the soil and remain so until spring. Then their activities and growth are renewed and continued until the larvæ are ready for pupation in May and June.

When the larvæ have completed their growth, they come to rest beneath the surface of the soil beyond the water's edge and there shed their skins. The pupa which is uncovered when the larval skin is shed is an elongate, dull yellowish creature about 1¼ inches long and armed with rows of stiff spines around the rear edge of each abdominal segment. These spines all point toward the rear and are useful to the pupa in wriggling upward until its head is pushed above the soil. This it does just before the fly emerges, a few weeks after the pupa is formed. The flies split the upper ends of their pupal cases and climb out to rest upon the sedges or grasses while the wings expand and harden. Flies emerge in June and July most commonly, though some irregular individuals may precede or follow those months. The flies continue to live all through the summer and usually die in September.

There is but one generation of horseflies each year. We may be thankful that they do not breed so rapidly as mosquitoes.

REFERENCES:

HINE, J. S. Ohio Acad. Sci., special papers No. 5, 1903.
HOWARD, L. O. *The Insect Book,* 1901.
HART, C. A. Ill. State Lab. Nat. Hist. Bul., Vol. IV, p. 242, 1896.

SCAVENGERS

Example 1. The House Fly (*Musca domestica* Linn.). Family, *Muscidæ.*

Probably no other insect is so generally familiar to man as the common house fly. In infancy we often learn "fly" among our first words and the familiarity continues even after we reach the mature age when our lack of protective hair gives flies such an excellent chance to disturb our rest out-of-doors. The house fly is found in all parts of the world where men live, excepting in the central parts of some of the larger cities where a fly is rarely found.

Why is the house fly so constantly associated with man and yet absent from the most crowded business districts where men congregate? In seeking the answer to this question, let us consider what attracts flies to any place. They are free, skillful fliers, able to go where they choose. Why do they choose some places and not others? Experiments carried on to determine what attracts house flies have shown: (1) that they are attracted to light and especially sunlight, except when it is exceedingly intense, and then they hunt shade; (2) that they are attracted for quite a distance by the odors of alcohol, acetic acid and carbon dioxide which are given off by ferment-

ing or decaying plants and animals; (3) that they are attracted very strongly by ammonia gas which is given off from feces and urine of animals, and that it is the presence of this gas which causes the females to lay their eggs; (4) that water or wet materials attract them. Light and water are often present where flies are not found so we must conclude that the odors from decaying organic matter, such as garbage and manure, are the factors absent in districts where flies are not found.

They have a keen sense of smell and can detect by means of their sensitive antennæ odors which escape us. Even the alcohol driven off in the baking of bread is enough to draw flies, and the cooking of foods containing vinegar will bring them from some distance away. Piles of wet fermenting weeds or grass may not offend our nostrils and yet it may attract flies. Their keen sight enables them to investigate everything within their vision but the sense of smell determines the locality in which they live. The most common sources of attraction to house flies are manure and garbage. The adult flies live upon the liquefied food which they obtain from garbage, manure, or from our tables. In the larval period their food is the nutriment found in manure, food which has been subjected to the digestive enzymes of, but not assimilated by the larger animals. The fly's sense of cleanliness is different from ours but it is not such a filthy creature as it is usually painted. Due to their small size, they can find much nourishment in what we consider entirely waste materials, and the fly does not consider the waste as filth any more than we consider potatoes dirty because they were grown in soil. The fly will not long tolerate any particles of dirt clinging to its body or hairs. Many times each day the fly may be seen cleaning its

body by rubbing and combing with its various legs until it is apparently immaculate.

Unfortunately the fly often visits various kinds of food before it cleans up. It sometimes visits material containing the germs of typhoid fever, summer diarrhœa, cholera, or infantile paralysis, and then comes to crawl upon our food leaving many of the germs there. There-

Fig. 106.—The House Fly: pupa, adult, larva, antenna of adult, rear view of larva. (From Howard.)

fore, we must consider the house fly as a menace to our health and a dangerous enemy to be disposed of. In cities the regular disposal of garbage provided for by sanitary laws, and the displacement of the horse by motor vehicles have decreased the fly nuisance, but in rural districts and small towns flies still breed in abundance. Probably they will continue to do so until state sanitary laws provide for the careful disposal of the manure of domestic animals on every farm. A single breeding center may be a source from which the flies will spread for miles around.

There are several other kinds of flies that are sometimes

found in houses, some of them smaller and some larger than the house fly, but not often carrying human diseases and not so abundant as this species. It is about one-fourth inch long and its general color is gray. The eyes are brown, the top of the thorax bears four dark stripes, and its body as well as its legs are beset with many hairs and bristles. The house fly never bites because it has no mouthparts capable of biting. It has a short, thick pro-

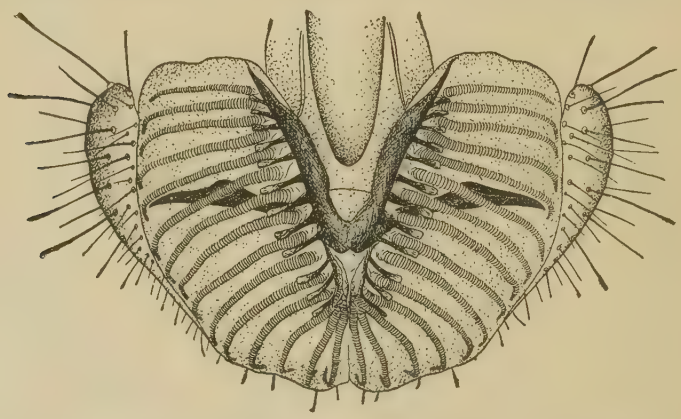


FIG. 107.—Lapping lobes at tip of the fly mouth. (From Smith.)

boscis on the end of which are two broad, rounded lobes used in feeding. By pressing these lobes against a surface a suction area is formed from which liquids can be drawn into the digestive canal. A salivary secretion may be expelled from the lobes upon the food to dissolve solid particles in order that they may be sucked into the mouth in solution. When not in use the proboscis is pressed back against the lower side of the head.

Flies are frequently seen to walk upon very smooth, vertical surfaces, such as windows and mirrors, where other animals could gain no foothold. The explanation

of this power of the fly is found in the structure of its feet. Each foot has two small, flat pads bearing on their lower side many tiny hairs which secrete minute drops of sticky fluid. The liquid from all of the hairs is enough to hold the fly's foot on the smoothest surface until it

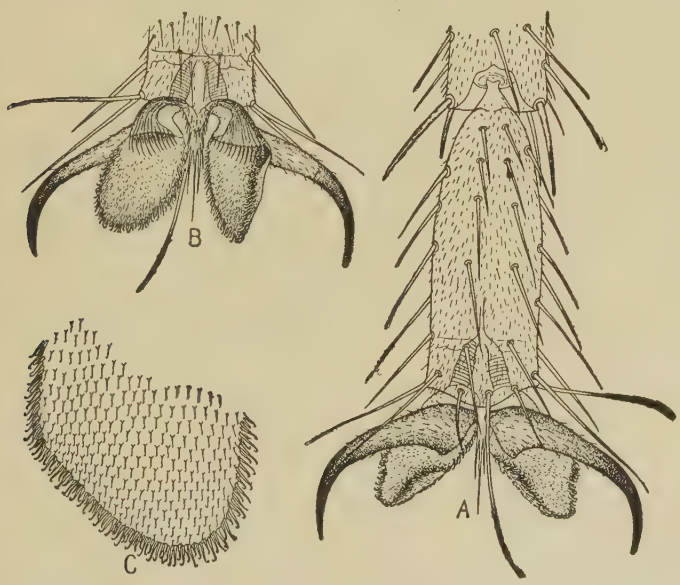


FIG. 108.—Foot of the House Fly: *A*, the last tarsal joint and claws; *B*, claws and pads; *C*, small section of a pad, showing hairs. (From Smith.)

is removed by muscular effort. Each foot is also fitted with the usual pair of claws which other insects possess and these are useful in walking on rough surfaces.

Flies are well supplied with air for their rapid flight. They have two pairs of thoracic spiracles and abdominal spiracles differing in number with the sexes. Males have five pairs while females have seven pairs. Leading from the spiracles are the ordinary tracheæ which all insects

possess in their bodies for carrying air to the tissues and in addition to these the fly has numerous thin walled bladder-like expansions of the tracheæ which can be inflated so as to fill most all the spaces between the organs in the body. As oxygen is needed by the wing muscles and nerves, it can be readily furnished from this abundant air supply.

House flies lay their eggs in fresh manure, chiefly horse manure, and even small neglected piles along the streets will be quickly found by them. The female fly lays from 25 to about 100 eggs at a time and she usually deposits several masses during her lifetime. The eggs hatch in less than twenty-four hours during warm weather, often in eight or ten hours, giving birth to tiny, transparent, legless maggots. These grow rapidly if the manure remains in the proper condition and they reach maturity in four or five days. If the manure becomes entirely dry or too hot the maggots die. The central part of large piles of manure is too hot for them and consequently they are found only about the edges of such piles. A temperature of 105 degrees F. is said to be fatal to the maggots and the interior of many piles reaches a temperature of 125 degrees or more. Manure which has been spread thinly over a field dries too quickly for the flies to be attracted to it unless the season or locality be exceptionally rainy.

The full grown maggot is about half an inch long with a shining yellowish white body. The front end tapers to a point bearing a tiny, black hook and the rear end is blunt with two dark spots on the upper part of its terminal surface. These dark spots contain spiracles for breathing air. The anterior hook is used by the maggot

to pull its body forward in moving about and to tear apart food particles. Only liquid foods or food divided into very fine particles and mixed with saliva can be sucked into the mouth, for no jaws are present. The hook is located in the mouth and can be withdrawn into its cavity when not in use. The maggot molts its skin twice during its growth and when it is full grown crawls to the soil at the outer edge of the manure. Sometimes it may crawl some distance away from the pile before finding soil in which it can pupate below the surface.

When the proper place is found for transformation the maggot begins to shrink, and its skin is not shed but turns into a hard, reddish-brown capsule called a puparium. Inside of this the pupa becomes a fly within four or five days. When the fly is ready to emerge it forces out part of the front wall of its head which is still soft, into a sack-like structure. The pressure of this structure breaks the end of the puparium and allows the fly to escape. The front of the face goes back into its proper shape, the skin hardens and the wings expand to their full size. After this a fly grows no more and has its final shape. The male flies are smaller than the females and both may be undersized if the larval food has been deficient.

About four days after emergence the two sexes mate and then a few days later the females begin to deposit masses of eggs. The average life of the adult fly lasts from two to three weeks and some live much longer than this. Each female may lay over 500 eggs before she dies. Generations follow each other from two weeks to a month apart all through the growing season. The cool weather of late autumn stops their activities and the cold weather

of winter destroys all except the pupæ, which in their hard shells remain inactive until the warmth of spring sunshine changes them into flies.

REFERENCES:

HEWITT, C. G. *The House-fly*, Cambridge Univ. Press, 1914.

RICHARDSON, C. H. *Jour. Econ. Ent.*, Feb., 1917, p. 102; Dec., 1922, p. 425.

SIMMONS, PEREZ. *Jour. Econ. Ent.*, Aug., 1923, p. 357.

A biting fly is commonly confused with the house fly. This is the stable fly, *Stomoxys calcitrans* Linn. This species is quite similar to the house fly in general appear-

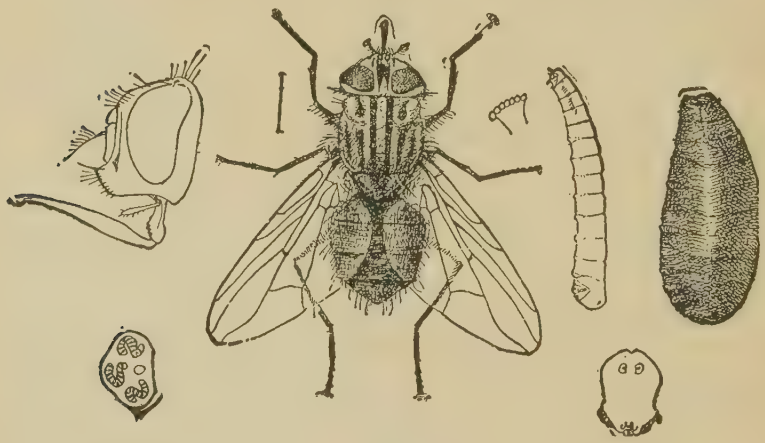


FIG. 109.—*Stomoxys calcitrans.* (From Howard.)

ance, but it is provided with a long, slender, piercing proboscis by means of which it can pierce the skin and suck blood. The stable fly is noticed about houses just before storms when it is seeking shelter and consequently many people have gotten the impression that the house fly bites before rains. The stable fly normally remains

near barns or animal sheds and breeds in wet bedding straw or decaying grasses.

The big noisy blue or green shining flies found about houses are known as "blue-bottle flies." They breed in garbage or other dead organic substances. Some of them breed in meat and are known as "blow-flies."

FIG. 110.—*Calliphora*, a blue-bottle fly. (From Howard.)

SCAVENGERS

Example 2. **The Little Fruit Flies** (*Drosophila melanogaster* Miegen). Family, *Drosophilidæ*.

In late summer and autumn, when grapes, peaches and pears are allowed to remain on our tables or about the kitchens, many tiny flies collect on the fruit. They are yellowish flies with bright red eyes and are small enough to pass through window screens. They come from the grocery or the orchard with ripe fruit, and if there is a

fruit with broken skin or juice on the outside, they find it and drink the juice. Like the house fly, *Drosophila* has on its proboscis a broad disk-like end which can be flattened against the surface of a juicy spot to form a suction area. It has no piercers for penetrating the skin but depends on juices which are exposed for its food.

The ancestors of the little fruit flies have been immigrants and some still come from the tropics as stowaways in vessels bringing bananas and other tropical fruits. In such cool climates as our Northern states have, *Drosophila* flies are unable to withstand the winters out-of-doors. Enough of them seem to succeed in finding food and shelter in fruit stores and storage rooms during the winter to perpetuate the species. Their numbers may be augmented each summer by the arrival of new immigrants with bananas.

They are interesting little flies to look at through a hand lens. The eyes are bright red and have little hairs growing upon their surface. The hairs arise from the angles where the 700 hexagonal lenses of each eye fit together. The body is yellowish with dark bands around the abdominal segments. The wings are quite clear, and beneath their bases a pair of tiny, club-shaped appendages can be seen, one on each side of the metathorax. These clubs grow on flies (*Diptera*) where the second pair of wings grows on other insects. If the clubs be clipped off the insect loses its balance when trying to fly and falls head first on the ground. They are called *"halteres"* which is the plural of the Greek noun *"halter"* and means balancers. In addition to their importance as balancers the *halteres* of flies are said to serve as hearing organs also. Hearing organs in insects are not perfectly understood but it seems probable that they are not capable of

perceiving a wide range of sounds such as we perceive. They may hear only sounds of a pitch similar to that of the buzzing produced by their own species and not perceive other sounds of higher or lower pitch. Those insects not producing sounds may not hear at all. At least we know that shouting and whistling close by them

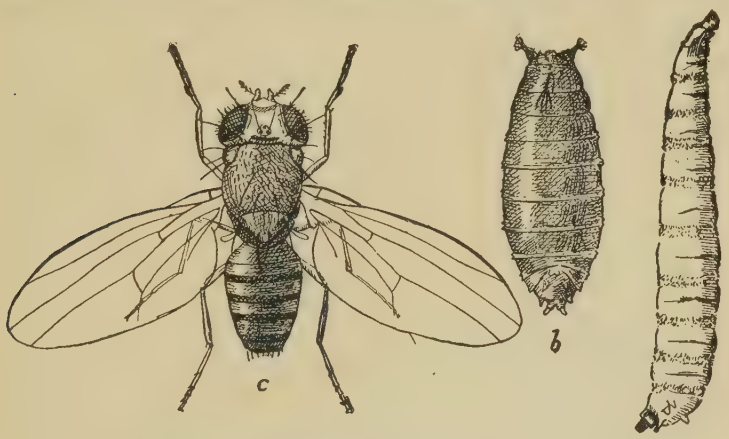


FIG. 111.—*Drosophila melanogaster: a,* larva; *b,* pupa; *c,* adult. (From Howard.)

will not affect insects which are very sensitive to other external stimuli, such as light, odors and touch.

Little fruit flies are drawn toward ripe and fermenting fruits by the odors of alcohols, acetic acid and lactic acid. If these products be placed in dishes away from any fruit the flies are attracted to the dishes. Removal of the third segment of each antenna will take away the fly's sense of smell, so that it remains indifferent to these odors and will settle on wax fruit as readily as real fruit.

The flies are attracted to fruits not only to get food for themselves, but also to lay their eggs on fermenting fruits. The eggs are tiny white, oval specks about $\frac{1}{50}$

inch long with two thread-like projections attached to the head end. These projections serve to keep the egg from sinking inside the soft fruit. When the larva is ready to hatch, it splits the shell over its head and squeezes out through the opening. It is a slender, white maggot much like a small house fly maggot except that the fruit fly maggot is more pointed at the posterior end where its black spiracular tubes project out beyond the tip of the abdomen. The maggot buries its body in the fruit with only the tips of the spiracular tubes exposed for breathing air. It has a pair of mouth hooks for tearing food much like the house fly maggot, but does not use these hooks in locomotion as the latter does. Movement of the fruit fly maggot is aided by several rows of tiny backward pointing hooks located on the lower side of each segment. The maggot in locomotion stretches its segments apart and then contracts them, causing waves of extension and contraction to pass forward along the body. The tiny hooks prevent the segments from slipping backward.

The chief food of the maggots is wild yeasts, which are microscopic one-celled plants. Yeast spores are carried by the air and when they find themselves in overripe fruit they use the fruit sugar for food. In digesting sugar they cause it to ferment with the result that the fruit gives off alcohols, carbon dioxide, lactic acid and acetic acid. Yeast cells grow and multiply when their food is found and are carried into the maggots' digestive system in the fruit juices. Possibly some bacteria connected with fermentation are also used as food by the maggots. Fruits naturally rich in sugar, such as banana or grape, offer more food for yeasts and consequently more for *Drosophila* maggots.

Like the house fly, *Drosophila* maggots molt twice during their growth and when full grown they crawl out of the fruit to find loose surface soil in which to pupate. When a suitable location has been found, the skin shrinks and forms a brown puparium within a few hours. Within this shelter the adult fly is formed in a few days. When the change is completed the fly breaks open the puparium by inflating the little sack-like outpushing of the front of the head similar to that of the house fly. The two sexes mate on the second or third day after the flies emerge and oviposition begins soon afterward. Both males and females have been observed mating with individuals of *Drosophila simulans* Sturt., a closely related species, but the flies resulting from this hybridization are always sterile.

About 8 to 12 days are required for a generation of *Drosophila* to be completed but the length of time required varies with the temperature. It has been found that a rise of 18° F. will reduce the length of larval, pupal and adult stages by one-half. The duration of the larval stage was found to be always 1.4 times as long as the pupal stage and about 0.2 as long as the life of the adult, when all three stages were kept at any constant temperature.

Drosophila melanogaster Miegen is a favorite animal for use in the study of genetics. It has a rapid succession of generations, is easily kept alive in laboratories and has become the standard example for laboratory instruction. About 250 mutant types have been discovered in this species. Eye colors from white to almost black, body colors from pale yellow to brown, wings short, long or absent, bristles changed in size and number, wing veins changed, giants and dwarfs are some of the characters produced by selective breeding.

REFERENCE:

STURTEVANT, A. H. *North Amer. Species of Drosophila,* Carnegie Inst., Wash., 1921.

GALL MAKERS

Example: **The Chrysanthemum Gall Midge** (*Diarthronomyia hypogaea* F. Low). Family, *Cecidomyiidæ.*

Chrysanthemum growers often find their plants being deformed by very small cone-like swellings or galls which appear on the chrysanthemum leaves, stems and buds. The galls may multiply very rapidly and the plants become so covered with them that their growth is checked and their color becomes sickly pale. The galls themselves are usually green in color but on out-of-door plants they may be red. The galls are made by larvæ of a tiny delicate fly known as the Chrysanthemum Gall Midge. It is a midget for its body is only about one-sixteenth inch long. It is very fragile, reddish in color, with long, slender, dark legs and delicate, transparent wings.

The female midges lay their tiny, orange eggs among the downy hairs which cover the surface of the plant. Usually they are placed on unfolding buds or young leaves. Each female may lay a hundred or more eggs and she usually places 15 to 25 in a group. Consequently the galls are usually found in groups rather than singly. The young larvæ, after breaking out of the egg shells, crawl about among the plant hairs until they find suitable places to enter, then they bore in through the epidermis to live among the plant cells. Their presence within causes galls to be formed by the plant in its growth. The exact method they use in stimulating the plant to

produce galls is not known. It may be mechanical stimulation produced by continued movements of the larva, it may be a chemical stimulation produced by an enzyme secreted in the larva, or it may be a combination of mechanical and chemical stimulations which makes the plant produce such deformities.

The gall which grows around the larva increases in size more rapidly than the larva and reaches its full size (about one-twelfth inch long) while the larva is still but a small, fat, yellow maggot with room to move some distance about the interior of its cell. The larva drinks sap which filters in through the walls of its cell from the plant tissues surrounding it. When the larva is full grown it is large enough to almost completely fill the cell. Then with head directed outward toward the apex of the gall it changes to a pupa. When the adult is ready to emerge from the pupal skin it begins to cut a hole through the apex of the gall by means of a pair of sharp horns which are formed on the head of the pupa. It forces its way outward until the front part of the body is outside the gall, then it breaks the pupal skin and wriggles out to rest on the leaf while drying.

The adult midges like cooler weather than most insects. They choose the coolest hours of the day to emerge from the galls, their emergence usually taking place between midnight and 9 A. M. The emergence from the pupal skin requires only a couple minutes, drying and hardening of the surface takes an hour, mating follows immediately afterward and egg laying is usually completed before the day has advanced far enough to become warm. Temperatures of 50° F. or lower are preferred by these insects for their period of activity. The adults live but a few

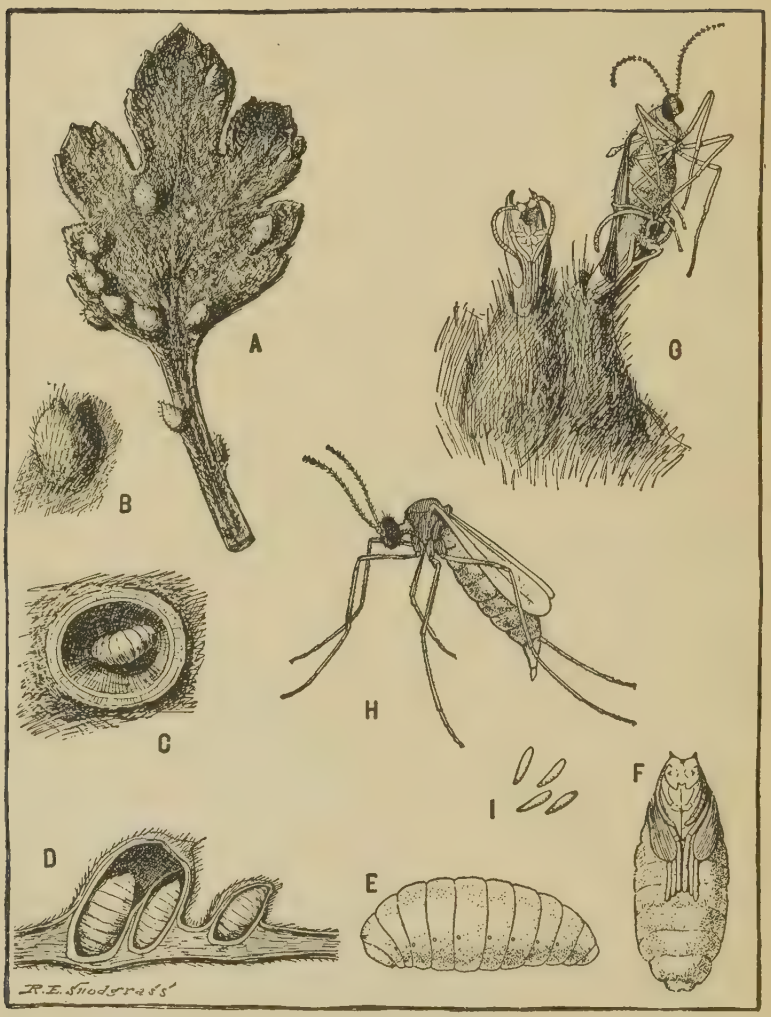


FIG. 112.—Chrysanthemum Gall Midge: *A*, leaf covered with galls; *B*, a single gall, more enlarged; *C*, gall cut open from above showing young larva within; *D*, two galls cut in vertical section; *E*, larva; *F*, pupa; *G*, fly emerging from a gall on right; discarded pupal skin remaining in opening of gall on left; *H*, adult female fly; *I*, eggs. (From Weigel and Sanford, after Snodgrass.)

hours, just long enough to provide for the perpetuation of the species. They take no food but depend on what they have stored within the body during the larval stage. The production of a large number of eggs in the short adult period is aided by the fact that there are more females than males, one of the latter mating with several females in rapid succession.

At Washington, D. C., where the life history has been studied, there are six generations per year. Three of them are completed between February and June, the other three between September and December. Each generation may require 20 to 50 days for its completion. The species goes into æstivation during summer weather, probably remaining in the pupal stage during that time. The explanation of this preference for cool weather is probably found in the fact that the species was formerly an inhabitant of the alpine regions of Europe on the wild ox-eye daisy, a close relative of the chrysanthemums. The species is now commonly found in greenhouses throughout North America, having been brought into this country on imported plants.

References:

Weigel, C. A., and Sanford, H. S. U. S. Dept. Agr. Bul. 883, 1920.
Snodgrass, R. E. 9th Ann. Rept. Ind. St. Ent., p. 149, 1917.

The family *Cecidomyiidæ* contains a large number of different kinds of small, delicate midges somewhat resembling mosquitoes. None of this family can bite and their most prominent features are the antennæ which bear many hairs arranged in whorls. Nearly all the larvæ live in plants and many of them produce galls. A few, like the notorious Hessian fly of wheat, make no galls but live between the stem and tight fitting leaves

of grasses instead of boring into the plant tissues for food. Many species also live in galls made by other species, and a number live in fungi.

The members of two genera, *Miastor* and *Oligarces,* have the remarkable habit known as *pædogenesis,* i.e., the larvæ, instead of maturing normally and changing

FIG. 113.—Young pædogenetic larvæ of *Miastor* in body of mother larva. (From Folsom.)

to adult midges, form several young maggots within their bodies. These young maggots break out through the body walls of the parent maggot and grow until nearly full sized, then they in turn reproduce another generation of maggots. This unusual habit of reproduction by larvæ is continued through several generations and then the larvæ of a generation transform into adult midges to reproduce like other species do.

FLESH BURROWERS

Example: **The Ordinary Cattle Grub** (*Hypoderma lineatum* Vill.). Family, *Œstridæ.*

Every stockman is familiar with the "grubs" which come out through the skin on the backs of cattle and ruin the hides. The flies which are the parents of these "grubs" are known by various names, such as "heel fly," "ox warble fly," "bee" and "gad fly." They have no mouths nor stings with which to inflict pain on the cattle, yet the latter fear them more than other insects and a single fly of this species (in northern states a closely re-

lated species, *Hypoderma bovis*) may stampede a herd. The effect on cattle is mainly a psychological one, for the fly visits them only to attach its eggs to a few hairs and causes no pain or irritation in doing this. But the sight of this fly causes them to lift their tails and run. If they can find water to stand in, or thickets of low growing trees and bushes to shade them, the cattle instinctively run to such places in their endeavor to escape the heel flies. The instinct is well founded, for, although the flies do no harm directly, their larvæ may do much harm later, and the flies will not follow cattle into such places to deposit eggs on them.

Fig. 114.—Ordinary Cattle Grub: female. (From Marlatt, U.S. D.A.)

Heel flies are about one-half inch long, hairy like bees, and are black and white except for a conspicuous fringe of reddish-orange hairs outlining the rear of the body. There are four bare shining stripes on the top of the thorax. If it were not for these stripes and the absence of a second pair of wings, the insects might easily be mistaken for bees. They are swift fliers and a heel fly may visit many cattle in the few days of adult life while it deposits eggs.

According to Seymour Hadwen the flies have a habit of settling on the ground in the shade of the heels of a standing cow, and stretching up their ovipositors, which can be extended like telescopes, they attach their eggs to

hairs at the back of the hoof. A line of 4 to 14 eggs may be glued to a single hair before the fly passes on to another place. In case the cow is lying down the fly may back up to her in the shadow and place the eggs on hairs anywhere along the line of contact with the ground. If cattle are moving the fly may dart swiftly to the legs or lower side of the body and leave its eggs. This disturbs the host so that few eggs can be laid at a time. The flies seem to prefer standing on the ground while ovipositing. They have small eyes set farther apart than those of most flies, their antennæ are also quite small, and they have no mouthparts. This lack of facial features gives them a blank and expressionless appearance. They are active only during the warm hours of the day from 10 A. M. to 4 P. M. and will not enter darkened buildings or heavy shade. Cattle standing in water seem to be safe from their visits also. The period of the year when heel flies are found varies with the temperature, it being February to June in Texas and April to July in Canada.

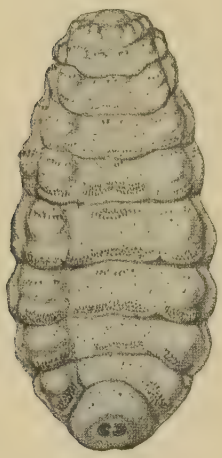


FIG. 115. — Ordinary Cattle Grub: full grown grub. (From U.S.D.A.)

The egg is an elongate, yellowish object about one-twelfth inch long and at one end it has a clasping pedicel which grips the hair to which it is applied while still soft. An egg hatches in 4 to 7 days after being placed on the hair. The egg nearest the skin hatches first and the others on a hair hatch in the order of their nearness to the skin. Upon breaking through the egg shell the larva crawls along the hair to the skin, being prevented

from falling by a coat of sticky material covering its body. Upon reaching the root of the hair the larva begins to use its mouth hooks to penetrate the skin of the host in the hair follicle. After several hours boring, the larva disappears into the inner layers of the skin. Larvæ from other eggs attached to the same hair may enter through the hole made by the first one hatched.

The host reacts to this attack by sending blood serum and white corpuscles to the spot in an attempt to repair the hole and kill the invader. The result is a swelling

Fig. 116.—Ordinary Cattle Grub: eggs attached to hair. (From Marlatt, U.S.D.A.)

and finally a scab to mark the place of entrance. The invading larvæ seem to burrow beneath the outer skin into the connective tissue where the blood supply is less abundant and they travel slowly upward in this tissue. For some time they wander about until the throat is reached. Here they enter the connective tissue of the œsophagus and move downward toward the stomach. When the diaphragm is reached it is followed upward to the backbone and entrance is gained between the vertebræ into the spinal canal within. The larvæ then wriggle along the canal until they reach the region of the loins, there they leave it and go up to their final position under the skin of the back. Undoubtedly some larvæ reach the back by routes which vary from the typical one just described, but they all seem to travel in the layers of loose connective tissue and it always takes

several months for them to reach the back. Cattle seem to suffer most when the larvæ are passing through the spinal canal and burrowing to the skin on the back. At this time the animals become nervous and they constantly lick the loin region. Soon after coming to rest in the final position on the back, the larva bores through the skin a small hole to which it applies its rear spiracles for air. When a scab forms over this hole the larva keeps it loose enough for air to pass in. The last 3 to 5 months of the larval period are spent in this position under the skin.

The larva or "grub," as it is commonly called, is a sturdy white, footless and headless creature like many other dipterous maggots, but with an array of short dark spines in rows around the body segments. The spines aid in moving upward through the slippery tissues of the host. It has a pair of small mouthhooks for cutting its way as it burrows, and on the rear end of the body are a pair of crescent shaped black plates containing the spiracles. When about 10 or 11 months old and full grown the larva is no longer white but its tough skin is gray or brownish in color. It is about one inch long, very plump and muscular, the segments of the body standing out distinctly with ridges and valleys. The food of the larva and the only food taken during the entire life cycle is probably the blood serum of the host, bathing the tissues in which the invader lives.

When ready to change to a pupa the "grub" forces its way through the hole in the skin which it has used as a source of air, drops to the ground and if the soil is loose, buries itself just beneath the surface. On hard ground it may remain on the surface. Here it contracts and its skin becomes a black, hard puparium. About a

month later the adult fly emerges ready to mate and to lay eggs. The flies are common in North America and Europe.

References:

Hadwen, S. Canada. Dept. Agr., Health of Animals Research, Scient. Bul. 27, 1919.
Hadwen, S. Canada. Dept. Agr. Bul. 29, new series, p. 16, 1923.
Marlatt, C. L. U. S. D. A. Div. Ent. Circ. 25, 1897.

The Northern Cattle Grub (*Hypoderma bovis* de Geer) is a close relative and very much like the Ordinary Cattle Grub in its habits, but it is larger and more commonly found in Canada and Northern Europe than in the United States. The flies of *H. bovis* de Geer appear a month later than those of *H. lineatum* Vill.

The family *Œstridæ* is composed of flies whose larvæ burrow in the flesh of various kinds of animals. The maggots of different species may live in different parts of their host's body. For example, the horse bot lives in the stomach while the sheep bot chooses the cavities of the head. Rabbits, squirrels, reindeer and a great many other animals have species of œstrids parasitic in them.

Sometimes blow flies (family *Muscidæ*) deposit their eggs or maggots in wounds of live animals and the burrowing maggots are then known as "screw-worms."

Predators

Example: **The Black-banded Robber Fly** (*Promachus vertebratus* Say). Family, *Asilidæ*.

A careful observer, when visiting patches of wild flowers such as those found along roadsides and fencerows, may in some years see long, lean, gray flies alighting on stems

of plants at the edge of an open space. These flies rest in this position so as to command a view of any other insects which may fly near. If a wasp or bee comes flying leisurely by, or a young grasshopper jumps into view, the fly darts after it, catches it in mid-air, wraps its long legs about the captive and carries it to some plant upon which to alight. Piercing a hole just back of the head, where the armor of the thorax is thinner,

FIG. 117.—*Promachus vertebratus:* adult male. (From Davis.)

the robber sucks out the fluids and soft viscera, leaving only the hard outer skin of its victim. Then it drops the empty skin and goes in search of other victims.

The robber fly is well fitted for its predaceous life. It has a pair of very large, shining eyes and the head is mounted on a narrow neck which can be turned so that the insect can see in any direction. The proboscis is long, sharp and stiffened by a heavy coat of chitin. The body is over an inch long and lean, but with long, stout legs, and the depth of the thorax shows that it contains very powerful leg and wing muscles. The wings are about three-fourths of an inch long, stoutly built and

capable not only of very swift flight but also of carrying the additional weight of the captured prey. The slender, pointed abdomen is marked with a conspicuous black band across the top of each segment. The head, excepting the dark eyes, is covered by a beard of long, blond hairs and most of the body has a sparse covering of short whitish hairs which give to it a general gray color.

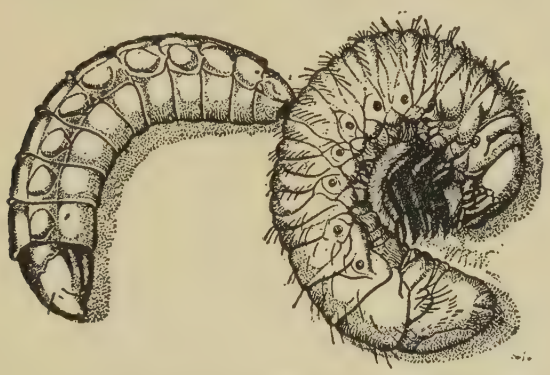


FIG. 118.—*Promachus vertebratus:* larva attacking a white grub. (From Davis.)

It is not known how long one of these flies may continue murdering its victims, but the flies may be collected from June to September during the years when they are abundant in the Northern states. The life habits are not well known, but due to the work of John J. Davis they are better known than those of most predaceous flies. After mating the female flies of this species deposit their eggs, usually several in a group, in the soil of meadow or pasture lands where grasses grow. The eggs are inserted into cracks if the soil is hard or if the soil is loose the mother may dig out a little cavity in which to bury them. The egg is a small, whitish, elliptical object nearly the size of a pinhead.

The larva after hatching burrows through the soil in search of smaller animals which it can devour. Probably it feeds at first on soft bodied insects and earthworms. Later it devours white grubs and has the reputation of being a valuable check on these pests. As shown in Fig. 118 it attacks the grub with its sharp jaws and having bored a small hole through the skin, pushes its head into the opening to eat the soft internal parts of its victim. It continues its search for grubs by burrowing through the soil and devours many of them during the long period of its larval life. Beginning its life as a larva in the late summer of one year it completes its growth in the late spring of the second year thereafter. Add to this period a month of pupation, a month or so of adult life, a week or so in the egg, and the life of an individual of the Black-banded Robber Fly becomes three years long. It is interesting to note that the life history of a white grub is also three years long. The fact that the eggs of both are laid in the same land during the same year also makes it seem probable that white grubs are the principal food of this robber fly larva.

FIG. 119.—*Promachus vertebratus:* pupa. (From Davis.)

It is a slender, creamy white larva with no legs and its body tapers toward each end. When full grown it is about one and one-half inches long. It has a tiny brown head which is mostly jaws

and is partly covered by the thorax. On the first segment back of the head and on the next to last segment of the abdomen, there is a brown spiracle on each side of the body. When ready to pupate in the late spring or summer of the third year of its life, it sheds the last larval skin and becomes a yellowish-brown creature over an inch long, heavily armed with spines and with spiracles on most of the abdominal segments. After about a month in this stage, it uses the spines to push its body upward to the top and comes to rest with the front half sticking up through the surface of the ground. The skin is soon split down the back, the fly wriggles out to dry itself and then is ready to begin its career of murder, or one might as well say, to begin hunting for its meat.

Reference:

Davis, John J. Ill. Nat. Hist. Surv. Bul., Vol. XIII, Art. V, p. 90, 1919.

The family *Asilidæ* is one of the larger families of flies and its members are found all over the world. All of them known are predaceous on other insects. They are usually long, slender flies like the species described above but a few are shorter and appear like bees. There are quite a number of other families of flies whose habits are little known but the larvæ are believed to be predaceous on insects either in the soil or in decaying matter.

Parasites

Example: **The Large-Plantbug Tachinid** (*Trichopoda pennipes* Fab.). Family, *Tachinidæ*.

Large, plant-eating bugs, such as the squash bug, the large green stink bugs and several coreid bugs, are fre-

quently destroyed by a species of tachinid fly which in its larval stage lives within their bodies. Carl J. Drake in

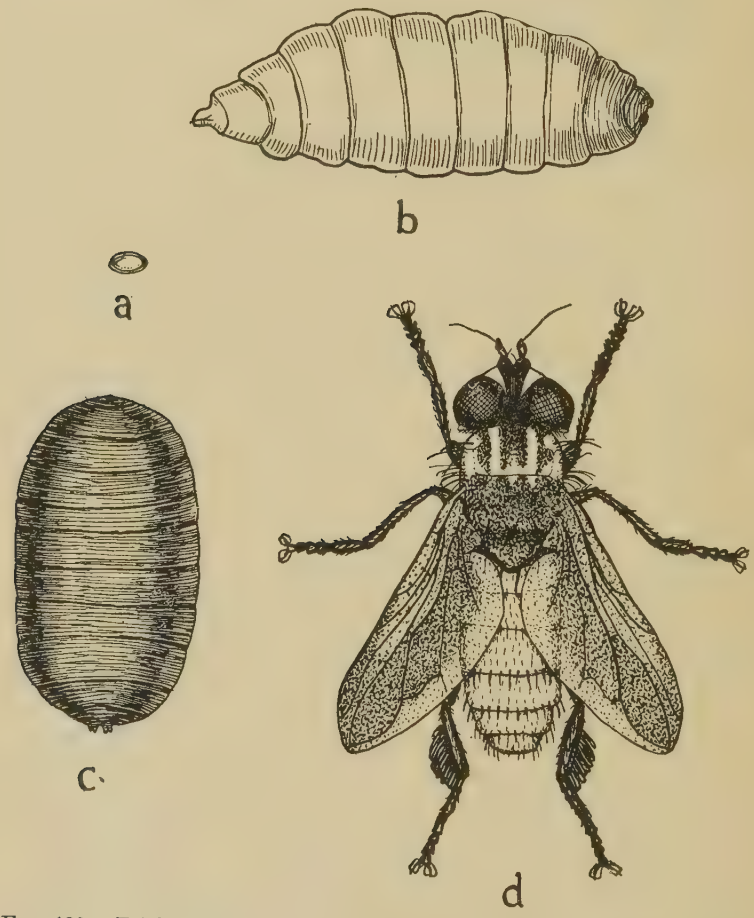


FIG. 120.—*Trichopoda pennipes: a,* egg; *b,* larva; *c,* pupa; *d,* adult.

Florida and Harlan N. Worthley in Massachusetts, while working upon the control of some of these bugs, found the parasite to be abundant and studied its life history.

The Large-Plantbug Tachinid fly resembles flies of the family *Tabanidae,* especially those found in damp woods and known as deer flies, but it is more gaily colored than they. It has a bright orange-yellow abdomen and black wings. The head and thorax are marked with yellow and black, while the big eyes are dark reddish-brown. Altogether its color is very striking and the fly, when resting in the sunshine on leaves of squash or flowers of wild carrot, with half-spread wings, readily attracts attention. Males have a long yellowish area near the front margin on each wing while the females' wings are uniformly dusky. The size of tachinid flies varies greatly with the amount of food taken by the larvæ. *Trichopoda* larvae which have matured within the bodies of very large bugs, such as the big coreids of the genus *Acanthocephala,* will become flies one-half inch long while larvæ maturing in the smaller squash bugs may become flies as small as one-fourth inch long. The flies of this species in Doctor Drake's collection show all degrees of variation between these sizes.

They love sunlight and hide during dark weather. For food they sip nectar from flowers by means of mouthparts like those of the house fly. The life of the fly is probably a week or more and its principal business is to mate and deposit eggs. On sunny days the females hover over plants looking for large bugs on which to deposit eggs. When a bug is sighted, the fly darts toward it and with lightning like speed, leaves an egg glued to the surface of the bug, on its back, its side, head, or on whatever part the fly's rear end happens to touch. She flies on to repeat the process on other bugs, leaving but one egg on each, although she may return and deposit another egg later on the same host if she

does not find enough different hosts for her supply of eggs.

The egg looks like a tiny, white dot on the surface of the host. About 30 hours after the egg is laid a tiny white maggot bores a hole through the shell on the side attached to the host. The maggot continues boring with its mouthhooks until it has penetrated not only the egg shell, but also the body wall of the host beneath the egg. Thus the maggot finds itself within the body cavity of a large bug, whose assimilated food and stored up fat form an abundant food supply for the invader. Since the maggot escapes through the hidden side of the shell it is impossible to tell whether the egg has hatched, without moving it.

The maggot grows to be a fat, white one, from three-eighths to one-half inch long and pointed at the front end much like a house fly maggot. It does little injury to its host until nearly full grown and then it gradually consumes the contents of the abdomen so that there is little left but the shell. The host is barely alive when the maggot works its way through the rear end of the body and drops to the ground to pupate. The host always dies soon after the parasite has left it. In the Southern states and during the summer in Northern states the maggot completes its growth in from 16 to 20 days, but in the North the last generation of maggots each year remains in the host all winter. The maggots are partly grown when cold weather stops the activities of their hosts and they go into hibernation. In the spring the host and maggot become active again and the maggot soon finishes its growth as well as the host. Many maggots undoubtedly perish, due either to their having reduced the host's vitality too much to survive the winter

or to their having been placed upon a host too small to supply enough food by the time the maggot needs it.

After having dropped to the soil, the maggot burrows beneath the surface an inch or so, its skin contracts a little and hardens to form the brown puparium in a very short time. The length of the pupal stage varies with the temperature. In midsummer it lasts from 11 days in the South to 19 days in the North, while the overwintering maggots which pupate in the spring require a month for pupation. When the fly is ready to emerge, it puffs out the front wall of its head, like the house fly, and breaks off the anterior end of the puparium, then it wriggles out and by alternately dilating the head and drawing up the rest of its body, it works its way out of the soil. Very soon after reaching the surface its wings have expanded, its body has hardened and gained its final color.

The Large-Plantbug Tachinid is strictly an American fly but is found widely distributed in both North and South America and the adjacent islands. It seems to choose most any of the larger *Hemiptera* which it can find for its hosts. There are three or more generations per year in the Southern and two in the Northern states.

References:

Drake, Carl J. Fla. State Plant Bd., Quar. Bul. Vol. IV, p. 67, 1920.
Worthley, Harlan N. *Psyche,* Vol. XXXI, pp. 7 and 57, 1924.

The family *Tachinidæ* includes a large group of flies important to us because they are parasites of other insects. As a rule the tachinids are medium sized or large flies and are usually gray like the house fly but with many bristles. Some, like the species described here, are bright colored and with few bristles. The larvæ of this

family live within the bodies of the larger species of caterpillars, wasps, bumblebees, grasshoppers, beetles and bugs.

The family **Sarcophagidæ** is known as the "flesh flies" and contains many species whose larvae are parasitic in grasshoppers and other insects. Flies of the family **Dexiidæ** resemble tachinids in appearance and their larvæ are believed to be parasitic in insects and snails.

In addition to the various flies and mosquitoes which have been mentioned, the order *Diptera* includes thousands of species of which only a few groups will be mentioned. **Crane-flies** are extremely long-legged awkward insects which usually remain in the shade of groves and woods but sometimes they are attracted to our houses by the bright lights. Their larvæ live in wet soil or decaying vegetation such as abounds on the floor of the woods.

The name "**midge**" is commonly applied to the tiny *Diptera* which are often found in swarms hovering in midair, and which seem to surround and follow us rather persistently when we run into a swarm. Most midges are harmless little creatures which are incapable of "biting," but a few species called "punkies," "sand-flies" and "no-see-ums," which occur in cool and mountainous districts, are extremely annoying because of their bites. The larval stages of midges are usually spent in streams, but some live in decaying vegetation and a few inhabit living plants. The tiny red "blood-worms" which occupy the floor of streams or ponds containing much organic waste are members of this group. Many of the larvæ make little tubes by gluing together bits of leaves or sand and within these tubes they live, feeding upon algae, bits of

organic matter, diatoms, or tiny crustaceans which occur in the water.

There is one small family of flies, called "**moth-flies,**" which resemble small moths because the wings are thickly covered with hair instead of being transparent like the wings of other flies. Their larvæ inhabit dark moist places where decaying organic matter is found, and the flies remain near the breeding places except when attracted to lights. Our most common moth-flies are found about sink drains, unclean cellars and sewage filter-beds.

There are thousands of species of tiny creatures resembling the midges but known as "**fungus-gnats**" because the larvæ usually live in fungi, such as mushrooms; some species live in decaying vegetation, and one group, called the "sciaras," contains species which sometimes destroy the roots of cultivated plants. Many of the fungus-gnat larvæ are found living together in crowds and in a few species they have been seen to move, just before the time for pupation, in a dense army, which appears at a distance like a snake.

Another group of *Diptera* which sometimes attracts the attention of the farmers is the family known as "**March-flies.**" These are robust, short-legged flies, usually dark in color. They commonly come out of the cultivated fields and meadows about the time of spring plowing and planting, and attract attention by alighting on the horses, sometimes in considerable numbers. They are harmless and their larvæ feed at the roots of grasses or in leaf mold.

The family **Simuliidæ** contains short hump-backed flies which have made themselves known to people in the vicinity of certain streams. In the mountainous regions of the northeastern United States they are known as

"black-flies." There the larvæ live attached to rocks in rapid streams and the flies are noted for their savage biting of fishermen and campers during May and June. They differ from most of the other pests which trouble the camper in that they operate in bright sunlight. In the lower Mississippi Valley a species known as the "buffalo-gnat" is a notorious pest of man and livestock.

Several groups of flies are noted for their resemblance to bees and wasps. Although these flies have no sting and are entirely harmless they undoubted enjoy some protection from molestation because of their resemblance to stinging insects. A family known as the **"bee-flies"** gains this resemblance by the dense covering of hairs over the body. The larvæ of bee-flies are parasites in the nests of bees, grasshoppers, and other insects. The family **Syrphidæ** contains some flies which resemble honey bees, some which resemble bumble bees, some resemble wasps and others have no resemblance to stinging insects. They are commonly called "hover-flies" because many species can hover in the air with rapidly beating wings. Most of them visit flowers to feed upon pollen and nectar, and some fly with a humming sound like that produced by bees. The habits of the larvæ vary greatly in different species; some act as scavengers in the nests of bees, wasps and ants; some live in foul water, others in rotten wood; still others live among colonies of aphids and devour them.

The inconspicuous gray flies of the family **Anthomyiidæ** often cause the horticulturist much grief because of the habits of some of the larvæ. Most of them probably live in decaying vegetation but one species, the "cabbage-root maggot," destroys the roots of young cabbages, radishes, turnips and cauliflowers; another, the

"onion maggot," burrows into the bulbs of onion plants causing decay to set in; another, the "seed-corn maggot," destroys sprouting corn and other plants before they are well established; other species mine in the leaves and stems of plants, while in another group of anthomyiids the larvæ live in the masses of seaweed cast up by the waves and the flies swarm over the seaweed all summer long.

A family of *Diptera* which is quite different from all normal flies is the **Hippoboscidæ** whose members are parasites living in the adult stage like lice on the bodies of birds and mammals. Instead of depositing eggs these flies rear their larvæ within their bodies and only deposit them when the larvæ are ready to pupate. One species, the so called "sheep tick," is wingless and lives in the wool, sucking the blood of the sheep.

References:

Comstock, J. H. *Introduction to Entomology,* Chap. XXVIII, 1924.
Imms, A. D. *General Textbook of Entomology,* pp. 592-657, 1925.

CHAPTER XX

ORDER SIPHONAPTERA

(Gr. siphon, siphon; apteros, wingless)

The members of this order are, in the adult stage, small, wingless, laterally flattened parasites, with mouthparts adapted for piercing and sucking the blood of their hosts, and legs developed for leaping. The larvæ are wormlike, white, legless, but very active insects, with distinct head and jaws for chewing solids.

Fleas, as *Siphonaptera* are commonly called, are well known because of their irritating bites and their power of leaping. They occur in nearly all parts of the world and most every kind of warm-blooded animal has at least one species of flea parasitic upon it. They are thin, flattened from side to side, usually about one-sixteenth inch long, chestnut brown in color, and provided with regular rows of backward-pointing spines on their bodies. The spines are said to aid fleas in their forward movement among the hairs or feathers of the host by preventing their slipping backward. Their eyes are very poorly developed, there being merely a tiny simple eye on each side of the head, and they can probably distinguish only between light and moving shadows. The antennæ are also quite small and lie hidden in grooves back of the eyes.

Fleas have sharp, needle-like mouthparts for piercing the skin of the host and forming a tube for sucking blood. During feeding, a glandular secretion like saliva is forced

into the wound and an irritation of the skin follows. During feeding, fleas also have the habit of taking as much blood as the digestive canal will hold and the remains of the preceding meal are often forced out from the anus to drop on the skin of the host near the wound made by the beak.

They are pests, not only because of their irritating bites, but also because of their disease carrying capacity. Because of their poorly developed sense organs, fleas commonly leap upon the wrong hosts and bite them. Thus a rat flea may carry the germs of bubonic plague from rat to man, the dog flea may carry Kala-azar from dogs to children, or it may carry tapeworms of the dog.

Fleas are famous for their ability to leap hundreds of times their length. To test its jumping ability, Mitzmain starved a flea 5 days and then measured its jumps. The four jumps recorded measured 10½, 11, 12 and 13 inches in a horizontal direction. Then he found that it could jump 7¾ inches perpendicularly.

They lay their eggs on or near their hosts and the larvae live in dust or earth containing particles of organic débris which they eat. They are often found in crevices or soil under the bedding or nests of host animals. Blood found within the alimentary canals of larvæ is not the result of their biting the hosts but is obtained by feeding upon the excreta of adult fleas. The larva is limited to locations where it may keep moist but not wet during most of the period of its development. Hot, dry weather stops its development while too much moisture kills it. Sandy coasts where dampness prevails for long periods are excellent locations for rapid breeding, as are moist earthen floors under buildings in drier climates.

Example: **The Dog Flea** (*Ctenocephalus canis* Curtis). Family, *Pulicidæ*.

Since dogs are companions of man and frequently have sleeping quarters in man's dwellings, dog fleas commonly become household pests. Cats likewise harbor the dog flea and are an important source of these pests in homes. Fleas from these domestic animals are the most common species found in homes excepting perhaps in coast towns where the true human flea prevails and in neglected buildings where rat fleas sometimes become abundant. The larvæ are found in places where the host is in the habit of lying and shaking its fur, but the adult fleas may jump about and enter other parts of the house. They leap upon the dog or cat to remain while feeding and while laying eggs, then they may leap to the floor and remain until hungry. If a human being walks near them when food is needed, they may leap upon his ankles for the next meal. Professor S. H. Gage, of Cornell University, although not an entomologist, decided to take advantage of this habit of fleas, to remove them from a room in one of the university buildings. Accordingly he tied sheets of sticky fly paper about the ankles of the janitor and kept him walking about the room for several hours with the result that many of the fleas were caught. Any larvæ remaining in crevices of the floor would, of course, soon take the places of those fleas captured.

The adult Dog Flea is about one-twelfth inch long, chestnut brown in color and of the shape shown in Fig. 121. Its body is very thin from side to side excepting after a hearty meal when it is expanded somewhat more. In moist places they may live for several months without food but in dry places they must have blood every few

days to keep alive. They are quite easily disturbed and frequently hop off of a nervous host several times during a meal. Under normal conditions, a female flea after mating, lays about 400 or 500 eggs, a few at a time, during the several months that she may live. She drops them loosely among the hairs on the host or sometimes drops them on the bedding and ground where the host is in the habit of resting. Soon after they are laid the eggs among the host's hairs are shaken off, so that they too eventually come to lie on the ground.

FIG. 121.—Dog flea: adult. (From Herrick.)

The tiny, oval, white eggs are about one-thirty-second of an inch long and may hatch in 2 or 3 days during warm weather. In the cool weather of spring and fall the egg stage may last 12 to 14 days. At the end of that period a tiny, slender, white, legless, eyeless, but active larva cuts its way through the shell with its jaws. It seeks at once to get away from light into some dust or crevice. Here it lives until it grows to be about one-fourth inch long and is ready to transform. The larval period may last from 7 days to 3 months, depending upon temperature, moisture and food. Under optimum conditions, with temperatures of 65° to 70° and high relative humidity, the larva may mature rapidly, but otherwise it grows very slowly. Its food is the particles of dead organic matter, such as crumbs of food, flakes of skin and hairs, which are found in the dust or soil. It

can travel rapidly by means of an up and down movement of the joint between head and thorax accompanied by pushing with the spines of the rear segments. It also has a pair of prolegs on the rear end which aid in pushing forward.

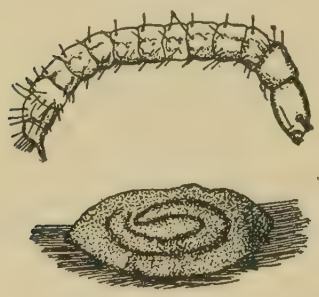


FIG. 122.—Dog flea: larva above, cocoon below. (From Herrick.)

When full grown the larva spins a thin, white silken cocoon over itself within which to transform. The cocoon soon collects dust particles over its surface, but frequently the outline of the larva lying in a curved position may be seen through it. Under best conditions the time in the cocoon is about 8 days but adverse conditions such as dry weather or winter may continue this stage for several months or a year. Within the cocoon the pupa forms and changes to the adult flea. The pupa is white and in shape resembles the adult flea with its legs free but held close against the breast. The adult when ready to emerge, forces its way through the cocoon and is very soon ready to leap upon some animal. The complete development from egg to adult may be passed in about 17 days when conditions are right, so there may be many generations during a year in climates where warm weather continues all the year. In our North-central states there may be 4 to 8 generations per year, the fleas being usually most numerous after periods of continued rainfall, during which the mortality of larvæ is less.

References:

Howard, L. O. U. S. D. A., Div. Ent. Bul. 4, p. 24, 1896.
Dietz, H. F. Ind. St. Dept. Conserv. Pub. 37, 1923.
Herrick, Glenn W. *Insects Injurious to Household,* p. 149, Macmillan Company, 1914.
Comstock, J. H. *Introduction to Entomology,* Chap. XXIX, 1924.

CHAPTER XXI

ORDER NEUROPTERA

(Gr. neuron, nerve; ptera, wings)

The members of this order have in the adult stage two pairs of thin, transparent wings, each with a network of many cross veins; fore and hind wing are similar in texture and shape; antennæ easily seen; mouth-parts for chewing. Larva with jointed thoracic legs and conspicuous predatory jaws. Metamorphosis is complete.

The order *Neuroptera* includes Lace-wings, Ant-lions, Dobson-flies, Fish-flies and a few uncommon families of insects. They are nearly all medium sized or large insects, ranging from about ¼ inch to 3 inches in length. The adults have chewing mouthparts and feed upon insects or other small invertebrates. Owing to their shy, retiring habits, they are not commonly seen. Many of them are nocturnal. Their conspicuous net-veined wings usually draw forth exclamations of wonder from the amateur naturalist when he finds one of the *Neuroptera*.

Larvæ of this order resemble the larvæ of carnivorous beetles and are apt to be confused with them. They are active, aggressive and equipped with arms for capturing insects to feed upon. In some families they have long, sharp jaws which are used to crush and swallow the body of the prey, while other families use the jaws only as piercing and sucking tubes to drink the blood of the prey. The larvæ of Dobson- and Fish-flies live in streams under rocks where they devour the young of May-flies and Stone-flies. Dobson-fly larvæ are large muscular insects, about 3 inches long when full grown

and are known as "Helgramites." They are a favorite bait for bass fishing. The larvæ of Ant-lions build small pits in dry soil where they lie concealed and capture ants or other insects which wander into the pits. They are sometimes called "Doodle-bugs."

Lace-wings and their larvæ live mostly on plants where they prey upon aphids, scale insects, mites and other small animals.

Fig. 123.—Dobson-fly, male with head of female above. (From Kellogg.)

Fig. 124.—Helgramite. (From Kellogg.)

Brown Lace-wings belong to the family *Hemerobiidæ* and Green Lace-wings belong in the family *Chrysopidæ*.

Example: **The Garden Lace-wing** (*Chrysopa oculata* Say). Family, *Chrysopidæ*.

On tall grasses, weeds and garden plants, during the last half of summer, a careful observer can usually find delicate, pale green, lace-winged insects with golden eyes. Their length from head to tip of the wings is three-fourths inch or sometimes a bit shorter. The body is very slender, much shorter than the wings and the muscles are not prominent. As compared to the flies, it is a very

FIG. 125.—Adult of ant lion. (From Kellogg.)

feeble flier in spite of its much larger wing surface. Except when disturbed it remains inactively resting, usually during the day, on the underside of some leaf. In the evening, it begins to move about, seeking food and a mate or depositing eggs. Quite often on warm, still summer evenings, it is attracted to lights and Lace-wings are probably more often found by the collector about lights than in the fields. One of the most extended studies of Lace-wings has been made by Roger C. Smith and the account given here is taken mainly from his observations.

Adults of the Garden Lace-wing, although very delicate in appearance, do not possess delicate appetites. They devour small aphids and other small insects quite readily.

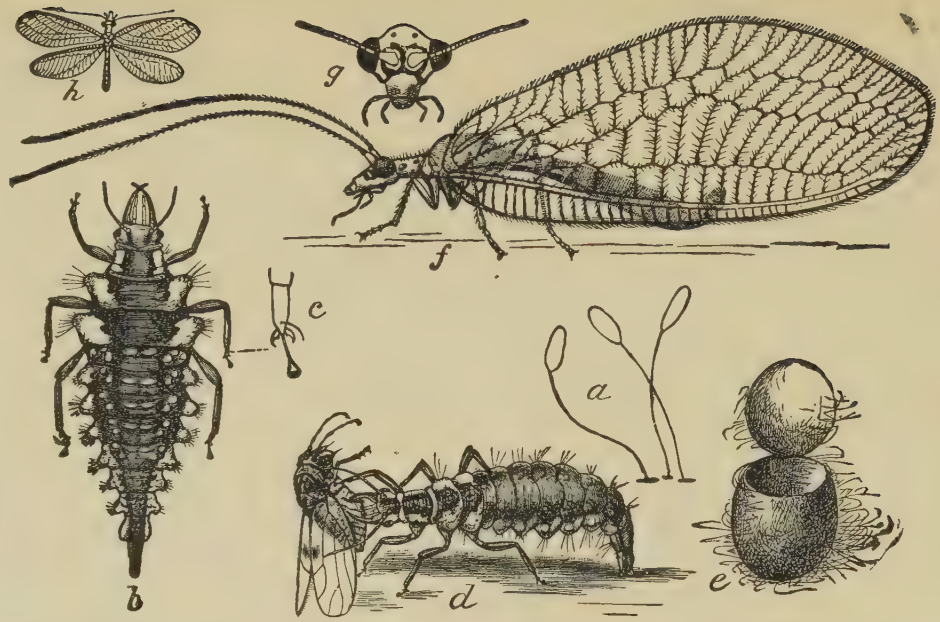


FIG. 126.—The Garden Lace-wing: *a*, eggs; *b*, full grown larva; *c*, foot of same; *d*, larva devouring a psylla; *e*, cocoon; *f*, adult; *g*, head of adult; *h*, adult, natural size. (From Howard, after Marlatt, U.S.D.A.)

One hungry adult was observed to eat seven cabbage aphids in succession. Water also forms part of their daily diet and may be secured from dewdrops or other sources. Since their bodies continue to be well nourished during this stage the adults live for several weeks. A female has been kept alive for 42 days and a male for 30 days but such long lives are probably exceptional. An ill-smelling, volatile excretion from small glands in the body is given off by the adult when squeezed or injured. This is said to ward off predaceous enemies and prevent them from eating Lace-wings.

After a brief courting consisting mainly of petting each other with the long antennæ, the two sexes mate and the females after a day or so begin laying eggs. The eggs are placed on leaves of various kinds of garden and field plants or may be deposited on objects near electric lights if the female happens to be attracted toward a light at a time when the eggs are ready to come forth. An instance is given of a student finding a Lace-wing at the light in his room one evening and the next morning finding eggs deposited on his coat which hung over a chair. Sometimes a single egg is left at one place but often an irregular group of several eggs is deposited. A female may deposit groups of eggs here and there each day until she has emptied her ovaries. There are records of females laying as many as 600 eggs before death.

The eggs of Lace-wings are very remarkable because each egg is attached to the tip of a long, slender stem and a group of eggs resembles the spore bearing stalks of some mold. In laying an egg the female first touches the tip of the abdomen to the leaf surface and forces a drop of gelatinous liquid out upon it. Then she raises the abdomen upward as high as she can reach, pulling the

liquid upward into a long, uniform thread, and immediately an egg is attached to its upper end. The egg is held there for an instant while the stem hardens, then the abdomen is pulled away with a jerk. The stem is strong enough to withstand windstorms and to furnish a rigid support for the egg. Egg and stem are pale greenish white and a little over ⅛ inch long. It is usually said that the mother places her eggs out on stalks because the first larva hatched would eat the unhatched unless some means were provided for preventing such cannibalism. The larvæ do eat first the eggs which have been accidentally laid without a stalk, and various other predaceous insects such as Lady-bird beetles are less likely to find stalked eggs, but stalked eggs are sometimes eaten by young Lace-wings and by ants which climb the stalks. So the stalk affords only partial protection to the eggs.

From 5 to 12 days after the eggs are laid the larvæ burst from them. Within the egg shell the larva is surrounded by a chitinous skin which is especially thick and hard in a small region over the head. Here the chitin forms a V-shaped structure with the point out and irregular saw-teeth along the margins. This is known as the egg burster. When ready to hatch the larva pushes the burster through the egg shell making a wide tear above its head. Then the head is pushed through the opening causing the shell to burst open wider, and at the same time the chitinous skin enclosing the larva is split. The insect then gradually works its way out of the shell and molts the skin at the same time. A half hour after beginning to hatch, the larva is ready to descend the stalk from the shell to the leaf. It manages to climb down the slippery stalk by means of grasping with the claws and

with a tiny bit of viscid fluid from the tip of the abdomen applied occasionally to anchor itself for an instant.

Upon gaining the leaf below the egg, a larva begins at once its search for food. It will eat aphids, insects' eggs, its brothers, or whatever animal food it finds and is able to pierce with its jaws. The mouthparts of these larvæ are very unique. Other insects which have a pair of stout jaws, set far apart and capable of being brought together at their tips, chew their food, but the Lace-wings do not use such a pair of jaws for chewing or crushing. Instead, they pinch the victim with the sharp points of the jaws until the points penetrate its skin, then they suck its blood and soft internal tissues through canals extending along each jaw into the mouth. Very little hard or indigestible food is taken into the mouth. The use of entirely digestible food is very necessary considering the structure of the digestive system, for no connection between stomach and anus is developed until the adult stage is reached, and therefore no undigested solids can be passed out of the stomach until that time. Liquid wastes can be removed from the body through the urinary tubes as in other insects. The rectum, which in most insects stores solid wastes until their evacuation, is in Lace-wing larvæ a silk making organ. Silk, used principally when the larva is ready to spin its cocoon, issues through the anus as a liquid and hardens on exposure to the air. The tip of the abdomen is used almost constantly by the larva to steady or anchor itself in walking on smooth surfaces or in handling a struggling aphid. A tiny bit of the liquid from the anus is used each time the tip is applied to a surface.

In feeding, the larva uses its jaws quite handily. It may spear a victim with one jaw, turn it about and

squeeze it with the other jaw until all the juice is out, then, reaching far out with the jaw on which the victim is speared, the empty shell is pushed off with the tip of the other jaw. A larva may eat from 10 to 20 large aphids in a day and a few larvæ, observed during the entire larval period, ate 150 to 200 aphids apiece in the 20 days of this period. Lace-wing larvæ are commonly called "aphis-lions."

Lace-wing larvæ molt 4 times, once when leaving the egg, twice during the larval growth period and once in the cocoon when the pupa is formed. Their molting is an interesting process. No food is taken just before molting, but a heavy meal is taken long enough before the process begins, to be well digested and furnish nourishment during molting. The larva when ready to molt fastens its anal end to some support, the legs become useless as soon as the process begins. The body begins to pull and twist until the abdomen is loose within its skin and pulls forward, then the thorax becomes loose in its skin. With a series of wave-like contractions, the body is crowded forward into the front part of the skin leaving a clear space in the anal end. The distended thoracic skin finally splits along the middle of the back and the insect pulls its body out through the opening, leaving the old skin still attached to its support. The entire process takes about 12 minutes but it is an hour or more longer before the larva has darkened to its final colors and is ready to attack an aphid.

After the larva has reached maturity and has taken a last full meal, it seeks loose soil or débris on the ground and goes below the surface to spin a cocoon. The cocoon is of white silk, oval in shape, papery in texture with straggling threads extending out. The cocoon is only

about ⅛ inch long, yet the insect which issues from it is, when its wings are expanded, six times that length. After spinning its cocoon the larva within will change to a pupa in 3 to 6 days in summer, but larvæ spinning their cocoons in late autumn remain unchanged until spring. After the pupa is formed and the last larval skin has been molted, it requires 5 days or more to complete the formation of the adult.

When internal transformation is completed the pupa pushes a circular lid off one end of the cocoon and climbs up from the ground onto some plant stem. Here it fastens its claws securely and begins to inflate or expand until it is several times the size of its cocoon. Then the body contracts and pulls away from the anal end of the pupal skin up toward the head. The thoracic skin stretches until it splits along the back, then the insect gradually pulls its head, antennæ, mouthparts, thorax, wings and abdomen free, leaving the linings of its tracheal tubes in the old shell. The adult walks up the stem away from the old skin about 20 minutes after the pupa begins the molting process. It assumes a position with head pointing upward and blood pressure then begins to expand the folded wings downward. They expand from the base toward the tip. A few minutes after the wings are expanded the adult with considerable effort voids the mass of solid waste which has been accumulating in the stomach during the larval and pupal periods, waiting for the completion of the intestine. This done, the Lace-wing is ready to begin its adult life of capturing food, seeking a mate, and, if it is a female, depositing eggs.

There are three generations in the Northern states each year and the winter is passed by larvæ of the third

generation in their cocoons under loose soil or leaves on the ground. The adults appear in May and June to deposit eggs of the first generation. About six weeks later the first generation becomes adult and about four to five weeks after that the second generation adults appear. In Virginia there are four generations per year and farther south there may be more. The species seems to be common over most of the United States, at least east of the Rockies. It is valuable to us as an enemy of aphids on cabbage, oats, corn, clover, etc., during the summer and autumn, but does not become active early enough to check early spring outbreaks of aphids.

References:

Smith, Roger C. Cornell Univ. Agr. Exp. Sta., Mem. 58, 1922.
Marlatt, C. L. U. S. D. A. Div. Ent., Circ. 7, 1895.

The order *Neuroptera* includes about twenty families but many of them are rare or uncommonly seen. Of these the large and striking **Dobson-flies** which have been mentioned on a previous page (248) probably attract the most attention. Every season entomologists receive specimens of these insects from interested citizens who regard them as rare curiosities. Another curious and more rare family is the *Mantispidæ* in which the members have long prothoracic "necks" and grasping front legs like those of the praying mantis. The habits of the various species of mantispids are not well known but it has been found that some of the larvæ live in nests of spiders and wasps where they prey upon the young of these animals.

The *Raphididæ* is another group of odd-looking insects. The adults have the general form of lace-wings except that they have long necks like mantispids. The

larvæ live under loose bark, especially on eucalyptus trees in California, but also on apple trees, where they eat other insects such as the codlin moth. The *Sisyridæ* includes a small group of insects resembling the brown lace-wings but the larvæ, although having the general appearance of lace-wing larvæ, are aquatic and seem to live always in fresh water sponges upon which they are probably parasitic.

The *Myrmeleonidae* (Fig. 125) are called "ant-lions" because of the habits of some of the larvæ which are found in dry or sandy ground. These larvæ dig pits in which to trap wandering ants and devour them. The ant-lion larva buries itself at the bottom of the pit, leaving only its long sickle-shaped jaws protruding. An ant wandering over the edge of the pit usually dislodges the sand or dust of the sloping sides and soon finds itself in distress. The ant-lion by jerking its head throws sand towards its victim repeatedly until the latter is brought within reach of the sharp jaws. The adults usually fly at twilight and are seldom seen.

The family with the long name *Coniopterygidæ* contains the shortest insects in the *Neuroptera.* They are less than an eighth of an inch in length and resemble the "white-flies" of the order *Homoptera* more than they resemble other *Neuroptera,* for the wings and body are covered by a white powder. The larvæ however have the form of other neuropterous larvæ and devour aphids, scale insects or mites which they find on the bark and twigs of trees.

References:

Comstock, J. H. *Introduction to Entomoloy,* Chap. XI, 1924.
Lefroy, H. M. *Manual of Entomology,* pp. 294-313, 1923.

CHAPTER XXII

ORDER DERMAPTERA

(Gr. derma, skin; pteron, wing)

The members of this order are flat, narrow-bodied insects with a prominent pair of stout, pincer-like appendages at the rear end of the body. Wings may be absent or present; when wings are present, the front wings are short leathery covers meeting in a straight line along the middle of the back, and protecting the hind wings which are membranous and folded beneath them. The mouthparts are for chewing and the young resemble adults.

The curious old English term, "earwig," is the common name of *Dermaptera*. Earwigs probably were known to crawl into the ears of persons sleeping on straw, during the Middle Ages, when this name became fixed upon the insects. They are common and often troublesome pests in Europe and in a few seacoast communities of the United States. They are nocturnal and their habits resemble somewhat those of cockroaches. Some earwigs invade houses and by night they get into pantries, cupboards, drawers, etc., while during the day the insects remain hidden in crevices. They also eat holes in the leaves of garden plants and may also eat the blossoms or fruit. Other species are found almost entirely in piles of old straw and other decaying organic matter, where they act as scavengers.

The order is not a large one, there being about 740 known species in the world. They vary in size from ⅛ to 1½ inches in length and are usually brown or black

in color. The life history of the order in general is very little known. One species, known as the common European earwig, has come as a stowaway to Newport, R. I., and Portland, Oregon, where its life history has been studied. Fulton states that it lives over winter in the

FIG. 127.—Female earwig in nest with her eggs. (From Fulton.)

ground in small cavities a few inches below the surface. The eggs are laid in the cavity during fall or early in spring, usually 40 to 60 in a place. The female guards and cares for the eggs and for the young earwigs until they leave the nest. Hatching takes place in late spring and the young remain in the nest until after the first molt. The female brings in food to them and wards off intruders with her pincers. Gradually the young ear-

wigs wander away from the nest and climb upon plants or other objects where they can get food, during the night. The female then raises a second brood during the summer.

References:

Fulton, B. B. Ore. Agr. Col. Bul. 207, 1924.
Comstock, J. H. *Introduction to Entomology*, Chap. XXII, 1924.

CHAPTER XXIII

ORDER COLEOPTERA

(Gr. coleos, sheath; ptera, wings)

The members of this order have in the adult stage a pair of hara, usually stiff, upper wings which meet in a straight line along the center of the back and cover a pair of membranous wings which are folded beneath them. The mouthparts are formed for chewing but in a few families they are located on the end of a slender snout which resembles the proboscis of sucking insects. The larvæ have jaws for chewing, and they usually have jointed thoracic legs, but no abdominal legs. The metamorphosis is complete.

Beetles, as the adults of *Coleoptera* are commonly called, are usually easy to distinguish from other insects, because of the hard upper wings fitting closely like a shell over the back. A few groups of beetles, such as the blister-beetles and "fire-flies," have flexible upper wings which sometimes confuse the student. *Coleoptera* is the largest order of all animals and contains over 195,000 species. In North America alone there are about 20,000 different species of bettles known.

The adults range in size from microscopic to some of the largest insects known. Their habits vary greatly; the majority are terrestrial, but many are aquatic. Many are predaceous on other insects and many eat plants, while others are scavengers. Next to *Lepidoptera* they furnish the most beautiful color patterns found among insects. Many have brilliant metallic colors while others have dark inconspicuous colors.

The larvæ vary so greatly that no general statements can be made concerning them. It is best to study them by means of examples. The pupæ have appendages free but folded closely against the breast. They usually transform in rude cocoons made of earth or bits of wood, but there are many exceptions. The eggs may be soft, oval ones, or hard shelled with various shapes, but they are not sculptured like those of *Lepidoptera*.

PREDATORS

Example: **The Green-headed Ground-beetle** (*Chlænius impunctifrons* Say). Family, *Carabidæ*.

The collector who turns over stones, boards or other objects which afford concealment on damp ground will sometimes find a black, oval beetle about one-half inch long with a shining green head and long slender brown legs. It runs rapidly out of sight into some crevice or under another stone and one must grab quickly to capture it. These beetles usually live alone for they devour any other insects or small animals which they can capture and it is not safe for one ground-beetle to trust another hungry one nearby. Muddy banks of streams or borders of marshes are favorite haunts of this species. They come out of their concealment by night to hunt their prey, which they crush and masticate with sharp, strong jaws. Night prowling mammals which feed upon insects are warded off by ground-beetles because of a vile smelling liquid given off, when the beetle is alarmed, from a pair of glands whose opening is just above the anus.

Female Green-headed Ground-beetles climb upon the leaves of cattails or other plants growing in wet places to lay their eggs. Each egg is attached to a leaf in a

tiny mud ball, usually placed several feet above ground on the lower surface of the leaf. Before laying each egg the female gets a coat of soft mud around the tip of her abdomen, climbs upon a leaf, slips the coat of mud from the tip of the abdomen onto the leaf, deposits an egg within the cell thus formed and then closes the cell by patting the mud at the open end down with her abdomen. She may construct from 7 to 20 such cells during one night and will probably make 80 or more during the months of May and June when oviposition occurs. The mud dries and sticks firmly to the leaf, concealing the egg from the eyes of predaceous insects. After an incubation period of a week or more the egg hatches and the young larva descends to the ground to live.

The larva as shown in Fig. 128 has jaws very similar to its parents' and it has about the same feeding habits, running about nights among stones and débris on the muddy banks of streams or other wet places, capturing any soft bodied insects which are not too active to escape it. It will greedily devour caterpillars, larvæ and pupæ of ants, crippled flies, etc. The larva has a dark brown armor of chitin, three pairs of well developed jointed legs for running, a pair of tails and an anal "proleg." This "proleg" is not an appendage but is merely the last abdominal segment which is turned downward and used to support the abdomen in locomotion. The tails bear several tactile hairs and the antennæ also bear sensory tubercles. The compound eyes of the adult are represented in this stage by a group of six simple eyes on a raised area back of each antenna.

The larva continues its predatory habits for about two weeks during which time it molts twice. At the end of this period it enters the ground and hollows out a cell

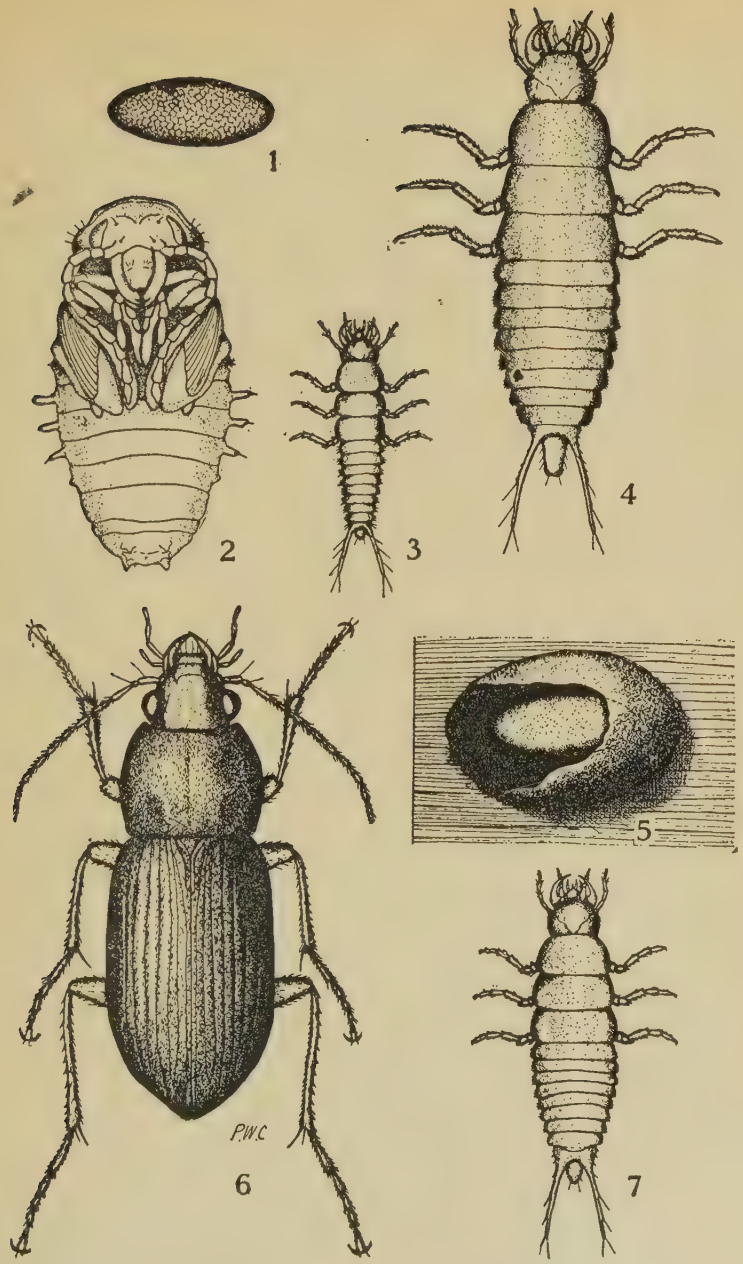


FIG. 128.—*Chlœnius impunctifrons:* 1, egg; 2, pupa; 3, newly hatched larva; 4, full grown larva; 5, mud cell on leaf opened to show egg within; 6, adult; 7, second stage larva. (From Claassen.)

in which to transform. Here the larva remains inactive for two or three weeks before it changes to a pupa. The pupa is of a cream color and shows plainly the appendages of the adult folded against the breast. After a week in the pupal stage, the adult beetle emerges from the ground.

The immature stages, egg, larva and pupa, require six or eight weeks for their completion. Since the eggs are deposited during May and June the adults of the new generation appear in late June, July and August. No records have been made of the length of adult life but it is probable that adults live nearly a year. When winter comes they are inactive during cold weather, but on warm days in late winter or early spring they become temporarily active enough to devour many other insects which have sought shelter under stones and have not awakened from their winter sleep.

The Green-headed Ground-beetles have been found in many parts of the United States and Canada east of the Rockies. They probably live in the areas throughout that region where moisture is abundant. Since they tend to reduce the total number of insects by their predaceous habits we consider them as beneficial to man.

REFERENCES:

CLAASSEN, P. W. *Annals Ent. Soc. Amer.*, Vol. XII, p. 95, 1919.
KING, J. L. *Annals Ent. Soc. Amer.*, Vol. XII, p. 382, 1919.

LEAF-EATERS

Example 1. **The Striped Cucumber Beetle** (*Diabrotica vittata* Fab.). Family, *Chrysomelidæ.*

Every grower of cucumbers, squashes or melons is familiar with the little black and yellow striped beetles,

about ⅕ inch long, which are so commonly found on these garden plants. When the plants are young the beetles often congregate on them in swarms and eat the leaves off, but later when the blossoms appear, the beetles seem to prefer these, although they may continue to eat leaves also. The same striped beetles may be found in autumn feeding on the blososms of goldenrod,

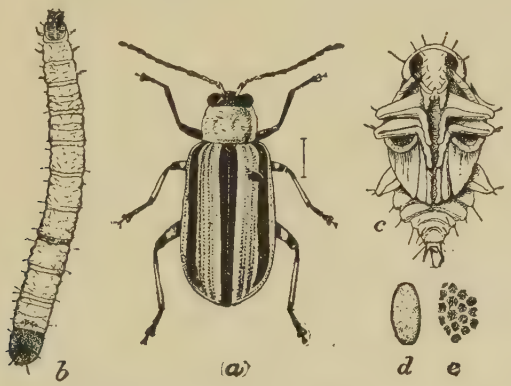


FIG. 129.—Striped cucumber beetle: *a*, adult; *b*, larva; *c*, pupa; *d*, egg; *e*, markings on egg. (From Chittenden, U.S.D.A.)

aster and sunflower. If they become exceedingly abundant, as they sometimes do where fields are entirely given over to cucurbits, the beetles may fly to beans, peas, corn or many other plants and eat holes in the leaves or other parts of these plants.

Striped Cucumber Beetles make their appearance with the advent of continued warm weather in spring. In the Northern states they appear on various kinds of weeds in late May or early June where they feed until cultivated cucurbits begin to grow. Then these are attacked and the leaves eaten for several weeks before the female beetles begin to deposit eggs. The tiny, yellow eggs about ¼₀

inch long are dropped into the soil about the bases of cucurbit plants or into cracks nearby. A single egg or a group of several may be dropped at one time and the female continues her egg laying for several weeks. Four hundred or more eggs are commonly laid by each female before her death.

The eggs hatch in from one to two weeks after being laid, the length of the incubation period depending on the temperature. Larvæ upon hatching begin to eat the roots and later eat their way into the stems of the plants. The larva is a very slender white elongate creature appearing like a tiny worm a little over ¼ inch long. It differs from a worm, however, in possessing a brown head and some short thoracic legs. The rear end of the body is also brown and carries a single proleg on the lower side to aid in locomotion. A pair of small but efficient chewing jaws is used to gain a living. The body is very poorly protected against drying, for the skin is quite soft except at the ends of the body where the dark brown chitinous plates cover it. Consequently the larvæ die unless the soil about them remains moist.

The larval period lasts from two to five or more weeks. When the temperature goes below about 70° F. the development of this species is retarded, but normal midsummer temperatures throughout most of its range are usually above 70° and the larvæ mature in 2 to 3 weeks, then. When full grown the larva tunnels through the soil a short distance from the plant where it has been feeding and makes a cell in the earth. Here the larva lies for a few days gradually becoming shorter and thicker, then it sheds its skin and becomes a pupa. The pupal period is about one week in normal midsummer

temperatures. At the end of pupation the adult beetle emerges from the soil to expand the wings and to dry. Then it begins to eat blossoms or leaves of cucurbits.

The time required for the development of a generation from egg-laying until the emergence of the adult is quite variable. In the extreme Southern states a generation requires about four weeks and as many as four generations may be completed in a year. In New England there is but a single generation and in the North Central states there seems to be a partial second generation. The latter condition may be illustrated by the situation in Iowa. Here the first generation develops in from 5 to 6 weeks and the adults emerge from early July until mid-August. Those adults emerging in July produce a second generation which will mature by early September but those first generation adults which emerge in August will not produce young the same year. They feed until frosty nights drive them into hibernation, when all the beetles of both first and second generation seek shelter under old leaves and rubbish in the fields, or among grasses and weeds along the fencerows and ravines. Many of the beetles perish before spring but many of them survive until the following July. The Striped Cucumber Beetles, like many other insects, are favored by a winter having a constant ground cover of snow, which protects them from drying out. They are usually more abundant during seasons that follow such a winter.

The species occurs throughout that portion of the United States east of the Rockies and in Canada. It is one of the most destructive pests of cucumbers and squashes, not only because of its using these plants as food for larva and adult, but also because it carries the

germs of wilt and mosaic diseases in its digestive system from diseased plants to healthy ones.

REFERENCE:

CHITTENDEN, F. H. U. S. D. A., Farm. Bul. 1322, 1923.

LEAF-EATERS

Example 2. **A Common White Grub** (*Phyllophaga fusca* Froh.). Family, *Scarabæidæ*.

The genus *Phyllophaga* contains about 100 species of very similar insects all found in North America. The farmer and gardener know the larvæ best and call them "White Grubs," while the people in towns are better acquainted with the adult bettles which are known as "May-beetles" or "June-bugs." The big, plump, brown beetles are attracted to the trees and lights of towns on spring evenings but at other times they are usually rural in their habits, living in fields and gardens. While the species are all quite similar, some of them live in one section of the country and some in another. Some prefer cooler climates and some prefer glaciated soil. One of the most abundant species in the northeastern part of the country, in such states as Wisconsin, Michigan, Iowa, New York, the northern half of Illinois, of Indiana and of Ohio, is *Phyllophaga fusca* Froh. Its range extends as far north as the Hudson Bay territory and as far south as Georgia, but it is most common in the states mentioned above and its grubs frequently cause heavy losses to the growers of those states.

The beetles of this species are plump, oblong, chestnut brown, shining on the back, hairy on the lower side, and about ¾ inch long. They have slender, spiny legs and antennæ which resemble small golf clubs. April, May

and June are the months when the beetles are active. During this period the clumsy beetles are often seen about lights or heard battering against screens and windows in an attempt to reach lights. They arrive just about dusk from the fields where they hide all day among the grasses or in the soil. The greatest numbers will come out on warm, quiet nights, for they dislike flying

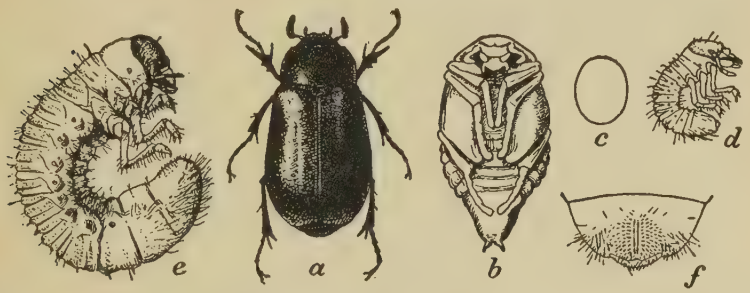


FIG. 130.—Common white grub; *a*, adult; *b*, pupa; *c*, egg; *d*, newly hatched grub; *e*, mature grub; *f*, last segment of grub from below. (From Chittenden, U.S.D.A.)

in strong winds and need a temperature of 60° or more to make them completely active. The real object of their evening migrations is to feed upon the foliage of trees, but many of them and especially of the males, are led astray by the bright lights, where they are frequently killed. Where great swarms of the beetles have been present, they sometimes are swept up in masses from beneath arc lights. Davis states that in one small Wisconsin town the beetles accumulating beneath the ten arc lights of the town were hauled away each morning for a period of ten days or two weeks, by the wagon load.

Many, however, are not tempted by the white lights, or do not succeed in reaching them, and spend the nights devouring the leaves of trees or shrubs. The species

seems to prefer ash trees but has been found feeding greedily on poplar, elm, walnut, willow, hickory and oak trees or even on gooseberry, blackberry and hazel bushes when ash was not easily found. Forbes states that there is a regular migration of beetles from fields to trees in the evening and that nearly all the beetles move simultaneously from the different fields. In June the migration takes place about 8 P. M. in Illinois and lasts but 15 minutes or so. They remain among the trees until the earliest birds begin to sing about 3 A. M. when the beetles begin to return to their hiding places and within 15 or 20 minutes they all disappear from the trees. Their feeding is so noisy that a flock of beetles in a tree often sounds like an April shower. When the beetles are extremely abundant, trees visited by them may be completely defoliated and the ground beneath covered with little black pellets of their excrement.

Although they all make their flights at the same time, May-beetles do not live in swarms. Each beetle goes its own way and each locality maintains its own population year after year without invasions of swarms from outside. Fields within a half mile of trees have many more beetles than those farther away from trees. While in the trees the males, which are more active, find the female beetles and mate with them. While hidden in the soil during the day females deposit their eggs. Each egg is placed in the center of a small ball of earth the particles of which are held together by a glutinous secretion from the mother. Each egg ball is located a few inches below the surface of the ground, usually from 1 to 8 inches. The egg is pearly white, about 1/10 inch long and is at first oval, but after 6 or 7 days it becomes swollen and almost round. Each female may lay from 50 to 100 or more eggs during

May and June. Several weeks are required for the development of the larva within the egg shell.

After hatching, in late June or July, the young grub eats particles of dead plants and sometimes small rootlets of living plants, which it finds by tunneling through the soil. Grubs are most commonly found in land which was covered with timothy, blue grass, or other grasses at the time the eggs were laid. The beetles seem to prefer such land to cultivated fields and will seldom oviposit in clean cornfields or other places where grass has not been allowed to grow.

As winter approaches, usually in October, the young grubs protect themselves from the cold by burrowing deeper into the soil. Each grub forms a small cell several feet below the surface in which it remains inactive until spring. Usually by early May they return to near the surface and greedily eat the roots of grasses or other plants if these have taken the place of the grasses. During the entire second summer the grubs continue to feed and grow. When October comes they again go below the frost line to live in cells during the second winter. The following May they return to their feeding on the roots of plants and by June they are full grown. Then an earthen cell is prepared a few inches below the surface and the larva remains inactive within it for a couple weeks before changing to a pupa. The pupal stage lasts about a month. In July the adult beetle is completed within the pupal cell, but it remains resting here until the following spring, when it emerges from the ground in April or May, three years after the egg was laid. In northern Wisconsin and probably in Canada, where summers are very short, the grub requires an extra year for its growth and the life history is com-

pleted in four years, but in Iowa, Illinois and Indiana the life history is as outlined above.

The grub is white, plump and rests curved like the letter U. Its head is tan, the body has numerous reddish-brown hairs, especially about the rear end, and the dark contents of the intestine is plainly visible through the skin of the abdomen. Along each side of the body a row of dark spiracles may be seen. It lives in well aerated soil where atmospheric air may be taken into the spiracles, and consequently the white grub is absent from soggy lowland soils. Its legs are well fitted for digging through the soil although not so highly specialized as the front legs of the cicada. The jaws are hard and strong, making very useful implements for loosening the soil as well as for chewing the roots of plants. Eyes are absent and would be of no use to the grub during its subterranean life, but a pair of rather long, 4-segmented antennæ contain sensory endings which enable the grub to locate its food. It molts but once each year, the third molt taking place when the pupa is formed. The pupa is white, inactive and has the appendages free but folded close to the breast like other coleopterous pupæ.

White grubs become serious pests when we plow under the grasses on which they have been feeding and plant corn, potatoes, strawberries or other crops with small root systems on the grass land. They must feed until the third year of growth is completed in the place where the eggs were laid and will take whatever food is available. To be safe from white grub injury, the grower must avoid planting such crops on soil where the grubs have begun their life cycle among grass roots and have not yet completed their feeding period. Crops like small

grains and clovers have such abundant roots that they supply food for the grubs without being seriously injured unless the insects are unusually abundant.

References:

Davis, John J. *Jour. Econ. Ent.*, Vol. 9, p. 261, 1916.
Forbes, S. A. Ill. Agr. Exp. Sta., Buls. 116 (1907), 186 (1916), 187 (1916).

Scavengers

Example: The Sacred Scarab (*Ateuchus sacer* Linn.). Family, *Scarabæidæ*.

In the large family to which the White Grubs belong are also a great many scavenger beetles. The largest of all beetles, tropical species measuring several inches in length, are of this group. In our country the black "tumble-bugs," or "pill-rollers" (*Canthon lævis* Dru.), which may be seen rolling balls of dung in pastures are often watched with interest by those who chance to come upon one. The most noted of the ball-rollers, however, is the Sacred Scarab of the Mediterranean region, whose likenesses were sculptured by the ancient Egyptians from the dawn of history. It is said that the soil of the Nile valley contains as many of these beetles per acre as Iowa soil contains White Grubs. In cultivating the soil, the Egyptians encountered them very commonly and the beetles became objects of great respect. They believed it to be a species composed entirely of males who reproduced themselves like the self-begotten Egyptian deities, and whose ball-rolling represented the daily turning of the sun by the sun-god, Kheperi. The fact that the beetles buried themselves and later reappeared sym-

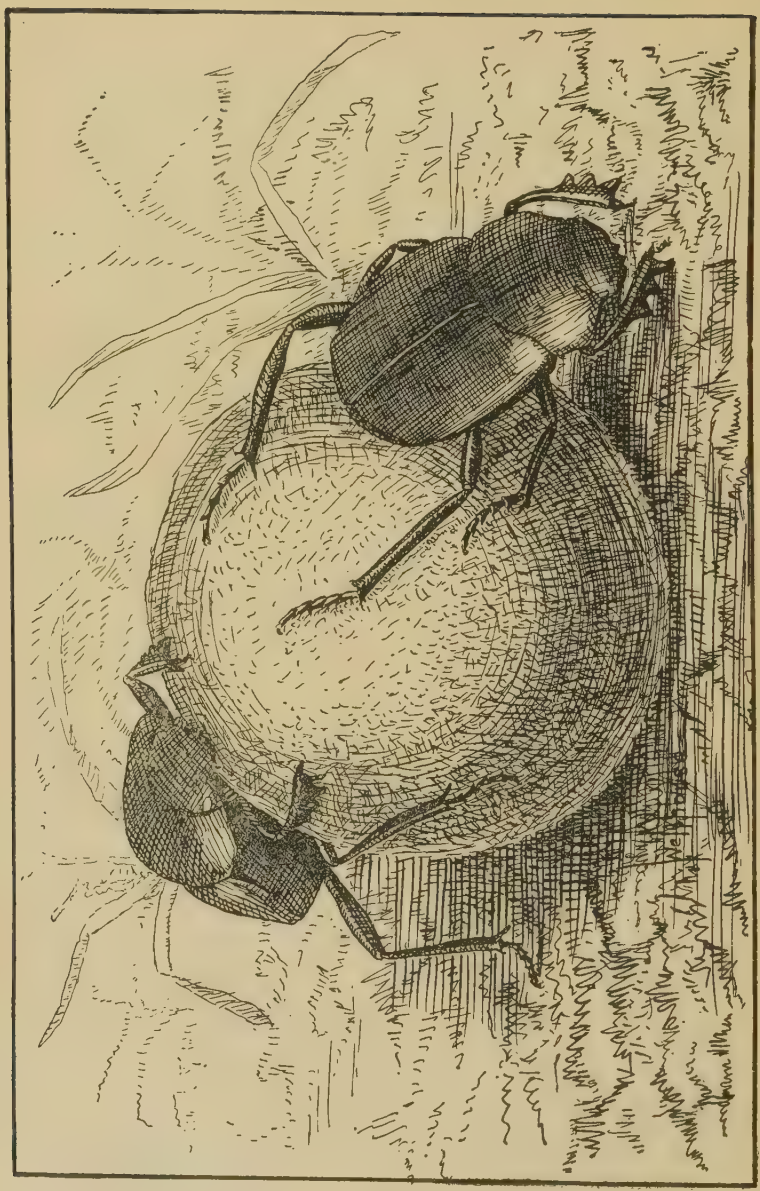


FIG. 131.—Two beetles rolling ball.

bolized immortality. Consequently, variously carved images of these beetles were worn by the people of three thousand years ago much as the crucifix is worn by many Christians today.

Many of the habits of the Sacred Scarab have been recorded by J. Henri Fabre, the French naturalist, who has written so many interesting accounts of insect life, and the facts of this discussion are taken largely from his work. Fabre watched the beetles in Southern France where they are common in the warmer districts close to the Mediterranean. They hibernate in the adult stage in the soil and appear in May to feed for several weeks before beginning to oviposit. The eggs laid in June and July hatch in from 6 to 12 days, the grubs become full grown in 4 or 5 weeks, the pupal period lasts about 4 weeks and the adults are ready to emerge at the end of this period. Adults are said to live for two and sometimes three years, depositing a few eggs each year. Thus young adults, their parents and grandparents may be working side by side, a situation not often found among

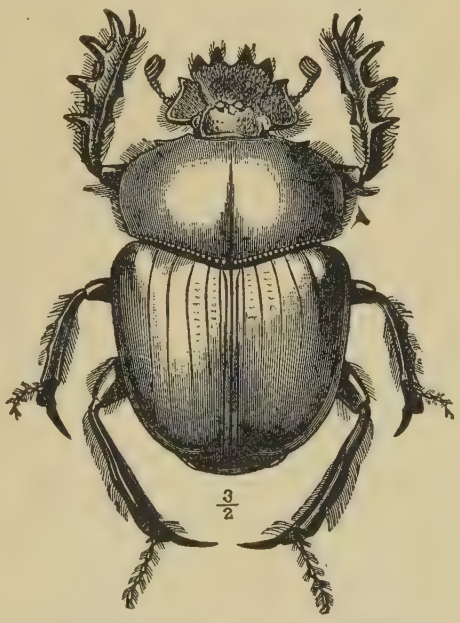


Fig. 132.—Sacred Scarab. (From Sharp.)

insects. The grubs resemble our White Grubs but are somewhat larger and lack the red hairs on their bodies. The beetles are coal black, about 1½ inches long and an inch wide. Their shape is shown in Fig. 132.

The habits of these beetles in rolling their balls are extremely interesting, and it is no wonder that they excited the admiration of the ancients. The balls are made from the moist droppings of herbivorous animals such as camel, horse, mule, or ox. In forming a ball, the spiny, front tibiæ serve as rakes to gather a mass of material, which is then patted into a perfect sphere by the flat sides of these tibiæ in conjunction with the other pairs of legs. At first, a ball the size of a pea is formed, then, as more material is added, it becomes the size of a walnut and, finally, the completed ball is often as large as a medium sized apple. As soon as the ball is completed, its maker clasps it with the hind legs (notice that the front legs have no tarsi with which to grasp it) and pushing with the front and middle legs, it proceeds to roll the huge ball. The beetle is moving backwards with head down and rear end in the air.

If the dung was found on hard ground, such as a footpath or stony part of the pasture, the ball must be rolled until soft ground is found in which to bury it. In reaching such a place the beetle must usually cross such obstacles as clumps of grass, small inclines or stones. The persistency of the beetle in overcoming such obstacles cannot but excite admiration in the observer. Often, in attempting to cross a slope or go up hill, the beetle loses control and the huge ball rolls to the bottom, perhaps knocking its owner over as it goes. Immediately the beetle is up and after its ball, pushing with all its might to regain the original path. The ball may get away

dozens of times and be persistently returned to its original path before the owner either succeeds in overcoming the obstacle or chooses a different route. Fabre tried to make the beetle give up its ball by thrusting a long pin down through the sphere, pinning it to the ground. After finding it impossible to push the ball in any direction, the beetle finally dug under it far enough to pry upward and raise the ball, on its back, until the pin was left below. Having succeeded in pushing it off the top of the pin, the beetle repaired the damage to its sphere and proceeded on its way.

Quite often a beetle in rolling its ball is joined by another of its species who attempts to steal the ball. The robber may be of either sex for both sexes look alike and both roll balls. Sometimes the robber mounts the big sphere and pushes the owner away until the latter upsets the invader by rolling the sphere. The two may wrestle on the ground while another thief rolls away the ball, or more often the two will join forces in rolling the ball, each awaiting the strategic time when he can make away with it. When two beetles join in rolling the ball, one pushes with hind feet upon the ball to guide it, while the other on the opposite side, pulls with front feet on the ball and hind feet on the ground. Occasionally one may cease pulling and clasp the ball tightly with all six legs. The other continues pushing and rolls both ball and beetle toward the goal.

When a suitable place is found the owner of the ball digs a hole in the soil by using his sharp toothed forehead and his front legs. He flings armfuls of soil behind him as he digs and soon gets out of sight in the hole. From time to time he returns to touch the ball and find that it is still there. Often the other beetle has begun

to roll it away and the owner must bring it back. If the owner stays out of sight too long in his hole, the ball may be gone entirely. When the hole is completed, it is about the size of a man's fist and opens at the top by a passage just wide enough to admit the ball. This is rolled in and the unsuccessful thief comes with it. The entrance to the hole is plugged with any leaves, grass or rubbish available, and the pair of beetles within begin an orgy of feasting.

They eat continuously day and night until the entire ball has passed into the alimentary canal, and a continuous black string of excrement several feet in length shows that the material has passed through the beetle's intestine, the nutriment being absorbed during its passage. After the entire ball has been eaten, the beetles come out of the hole and each goes his way to make another ball or steal one. The plates which make up the club of each antenna may be seen to spread in an effort to smell more food, much like a horse distends its nostrils to smell hay. Having located an odor in some direction, the beetle unfolds a pair of membranous wings from beneath the hard upper wings and flies away.

In June and July the females vary the ball-rolling habit by making a different sort of ball in which to place an egg. This time more finely divided and moister material such as the droppings of sheep is required. It is rolled as a ball to soft ground, an underground chamber the size of a fist and deep enough to insure a 4-inch roof of soil over it, is constructed. The ball is rolled into the chamber and pressed into the shape of a pear, about 1¾ inches long. The outer layer is packed hard by means of the front tibia so that the surface of the pear is a firm crust. Inside the neck of the completed pear a

little cavity is made and a pearly white egg 3/8 inch long (very large for an insect egg) is stuck to the ceiling of the cavity. The egg does not touch the pear shaped mass at any other point except at the place of its attachment. The egg having been deposited, the small end of the pear is closed and the beetle climbs out of the chamber and covers it with a layer of soil 4 inches thick.

In spite of this protecting layer of earth, the sunshine heats up the chamber so that the crust of the "pear" is soon baked and becomes quite hard. This hard crust protects the interior of the pear from drying. After the egg has hatched, the grub eats the interior of the pear, transforming the filthy material into a plump, ivory white, shiny body, curved U-shape like our common White Grub. That portion of the material which the grub cannot digest is passed out from the anal slit and plastered on the walls of its house to strengthen them where the interior has been eaten away. By the time the pupa is formed, the walls of the pear have become so hard and thick that the observer can only crush them with a rock or other heavy instrument. When the adult is completed, it is unable to cut its way out of the prison and must await the softening action of autumn rains. As soon as released, the new beetle joins its elders in ball-rolling.

Our common American ball-roller, *Canthon lævis* Dru., is supposed to have similar habits of life.

References:

Fabre, J. H. *The Sacred Beetle and Others,* Dodd, Mead and Co., N. Y., 1918.

Wade, J. S. *Canad. Entomol.,* Vol. 54, p. 145, 1922.

BORERS

Example 1. **The Round-headed Apple-tree Borer** (*Saperda candida* Fab.). Family, *Cerambycidæ*.

Apple growers are troubled by many insect pests but there are none more disheartening than those which kill the trees by boring into their bases. Throughout the eastern and central states, wherever apples are grown, it is not uncommon to find trees killed by the Round-headed Apple-tree Borer. In some orchards the borers are very abundant, while in others they seldom give any trouble. Investigations of this spotted distribution have led to the conclusion that orchards planted in the vicinity of uncared for wild host plants will probably become infested with borers, while orchards in districts where the wild hosts are absent will not be infested.

The wild host plants of the borer are service berry (*Amelanchier*), mountain ash (*Sorbus*), wild crabapple (*Pyrus*), hawthorn (*Cratægus*) and in some districts the cultivated apple, itself, which has become wild. Of these, service berry and wild apple are the preferred hosts. The stems of either of these may be killed by the borers but new stems will shoot up from the roots and thus keep a continuous supply of new food for the borers unless they become very abundant. When shoots from the roots surround the old stems woodpeckers are prevented from digging out the borers so efficiently and the result is that clumps of service berry and wild apple form breeding centers for numerous borers. From these breeding centers the adult beetles may fly to apple trees which are planted several hundred yards away.

The beetles of this species are very striking in their appearance. They are long, slender insects with three

broad cinnamon brown stripes extending the full length of the back from eye to tip of the wings. The rest of the body is white or grayish white. The male is about ½ inch long and the female ¾ inch long. The long antennæ, often longer than the body, are characteristic of the entire family *Cerambycidæ*, and give to beetles of this family the name, "Long-horned Beetles."

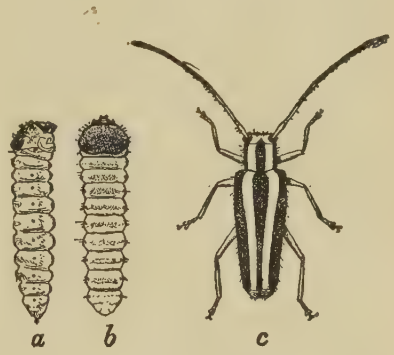


FIG. 133. — Round-headed Apple-tree Borer: *a*, *b*, larva; *c*, beetle. (From U.S.D.A., after Chittenden.)

The beetles of the Round-headed Apple-tree Borer are usually present for about two months, resting upon the leaves or bark of host plants, in any locality where the borers occur. In the extreme Northern states they are seen in June and July, but throughout the rest of their distribution they are found in May and June. They bask in the early morning sunlight on top of the foliage and sip the dew. As the day grows warm, they are often found in the shade gnawing the bark of twigs with their stout chewing mandibles. Sometimes they cut ragged holes about the edges of leaves, or may be found working with their mandibles at the mixture of "sawdust" and sap exuding from borer holes in the trunk of the tree. In the late afternoon, just before twilight, they may be seen again on top of the foliage resting or courting. On cloudy days they may remain exposed on the foliage all day and eat a leaf occasionally. During very dark, rainy days and at night the

beetles usually remain hidden among the branches. The two sexes mate several times and each female deposits about 25 eggs before her death. She lays these, usually, several at a time and quite close together, then she may wait a few days before depositing another group.

In preparing to lay an egg, the female takes an oblique position on the bark at the base of the tree and with her jaws, makes a little slit through the bark about ⅛ inch long. After the slit is completed she turns about and inserts the tip of her abdomen into the opening. With considerable effort she forces it in under the bark and leaves an egg there, a little to one side of the slit. Then she fills the opening with cement from her glands and is ready to make another slit adjoining the first one or a short distance away. After the batch of eggs is deposited the beetle moves away up the trunk or on the ground to fly to another tree. The eggs are usually deposited within 6 inches of the ground.

The yellowish egg is oval, about ⅛ inch long, and flattened by the pressure of the bark. It hatches after 2 or 3 weeks and a tiny, legless, cream-colored larva with tiny brown head but strong black jaws emerges. On top of its thorax are many small, brown tubercles and along the sides of the body are a few short, stiff hairs near the dark spiracles. The segments of the body are quite distinct due to the unusually deep dividing lines between them. The first segment of the thorax is much larger in diameter than the head which appears to be sunken into the thorax. The larva begins to feed at once after leaving the egg and soon eats out a broad, irregularly circular burrow between the bark and wood around the point where the egg was laid. At this stage of its life, growth

is rapid and the borer soon forms a broad tunnel under the bark which may extend in any direction from the egg.

The tunneling is at first confined to the inner bark and the point of injury usually shows from the outside as a dark, slightly sunken area. The presence of larvæ may also be detected by wet "sawdust" which is pushed out through the slit where the egg was laid, when the larva first begins to feed. The larva eats much indigestible cellulose which is passed through the intestine and soon this sawdust-like material accumulates in such quantity that the larva does not attempt to push it outside the bark. It is then packed in the tunnel behind the larva. Occasionally larvæ gnaw small holes through the bark either by accident or for the purpose of pushing out masses of excreta, which may be in their way. The larva always keeps a small, clear space about it and usually rests in a U-shaped position in this clear space. Although legless, the larva is able to keep from slipping by means of rough pads on the under surface of the abdomen and by the U-shaped position assumed when pushing the mandibles into hard wood.

As winter approaches there is a tendency, especially in Northern states, for the larva to burrow downward beneath the soil line and tunnel into the bases of roots. During cold weather it remains dormant in the burrow and begins its activities in the spring just before apple-blossoms open. Sometimes during the first summer the larva bores deep into the wood but usually this is delayed until the second summer. In small trees the tunnels extend into the heart wood but in older trees they seldom extend more than an inch beneath the bark. The tunnels

in the wood, like those in the bark may extend both above and below the soil line and are irregular in shape.

The larva when full grown measures about 1¼ inches long if it is male and 1½ inches long if it is female. The time required for its growth varies with the length of its feeding season and although protected from sudden weather changes, its feeding season is affected by temperature. In the Carolinas it is full grown by the end of the second summer, in Maine it often requires four summers, but in the most of its range three summers are sufficient for its growth. At the end of the third summer, or the last summer before pupation, the larva tunnels upward and outward until it rests in a chamber just beneath the bark, and from 4 inches to 2 feet above ground. This chamber is slightly broader than the rest of the burrow, the upper end next to the bark is packed with "sawdust," and a considerable space below the larva is packed with short, excelsior-like wood fibers torn from the walls in making the chamber. Here the full grown larva rests all winter and changes to a pupa the next spring about the same time that the apple blossoms open.

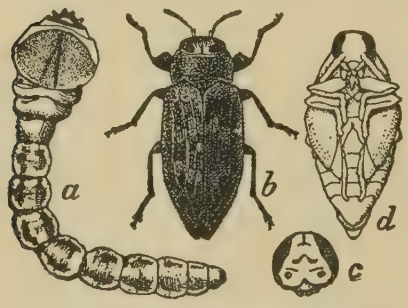


FIG. 134.—Flatheaded tree borer: *a*, larva; *b*, beetle; *c*, head of male beetle; *d*, pupa. (From U.S.D.A., after Chittenden.)

The pupa is soft, creamy-white at first but gradually turns darker. The appendages of the beetle and especially the long antennæ are easily seen curved downward and held close to the body. It rests head upward in the

chamber for about a month, until the beetle is completely formed, and then the insect must wait 5 or 10 days longer for its jaws to become hardened before it can gnaw a way out through the bark. The exit holes are round and those made by females are slightly over ¼ inch in diameter, while those made by males are less than ¼ inch.

The complete life of a generation is usually three years, but in the South it may be two years and in the extreme North four years. The name "Round-headed" is applied to this species as a distinction from another borer commonly found in apple trees and known as the "Flat-headed tree borer." Larvæ of the latter species have the thorax wide and flat, while larvæ of the former have the thorax more nearly round.

References:

Brooks, Fred E. U. S. D. A. Bul. 847, 1920.

Becker, Geo. G. Univ. Ark. Agr. Exp. Sta., Bul. 146, 1918.

Borers

Example 2. **The Pine Slash Bark-beetle** (*Pityogenes hopkinsi* Swaine). Family, *Scolytidæ*.

Piles of branches, tops and culls which are the refuse from lumbering operations are known as "slash." Slash piles, if they are left unburned, form a dangerous breeding place for many species of borers which will also attack living trees and destroy them. Some of the borers belong to the Long-horned beetle family (*Cerambycidæ*), some belong to the Flat-headed borer family (*Buprestidæ*), while many of them are very small beetles which never bore deep into the wood but remain under the bark. These beetles form systems of tunnels between the bark

and wood which groove both bark and wood in such a way that when the bark is removed it appears to have some hieroglyphics engraved on its surface. The members of the family *Scolytidæ,* to which the little beetles belong, are known as "bark-beetles" or "engraver" beetles.

FIG. 135.—*Pityogenes hopkinsi,* adult female. (From Blackman.)

The most common Bark-beetle found in pine slash in the eastern United States and eastern Canada is *Pityogenes hopkinsi,* which we may call the Pine Slash Bark-beetle. It breeds abundantly in recently cut pine branches and in unhealthy living pine trees, such as young pines recently transplanted, or shaded branches on older trees. It prefers white pine as a host plant but will breed in Austrian pine and other thin barked pines.

The Pine Slash Bark-beetle like other bark-beetles is a comical looking little creature with his thorax pulled over his head like a hood. (Fig. 135.) He is only about one-twelfth inch long, black all over excepting the rear two-thirds of the upper wings which are brown, and he wears blond whiskers as well as scattered hairs all over the body. Although so tiny, he is as strongly built as a bulldog and has a similar tenacity. The top of his thorax is roughened by the presence of many short stout spines directed backward and on the rear of each upper wing there are three large tooth-like spines. He has a short snout with powerful chewing jaws, and arising just in front of each eye is a short antenna with a round club on its outer end.

The male of this species is a far more important member of the household than the male of most insect species.

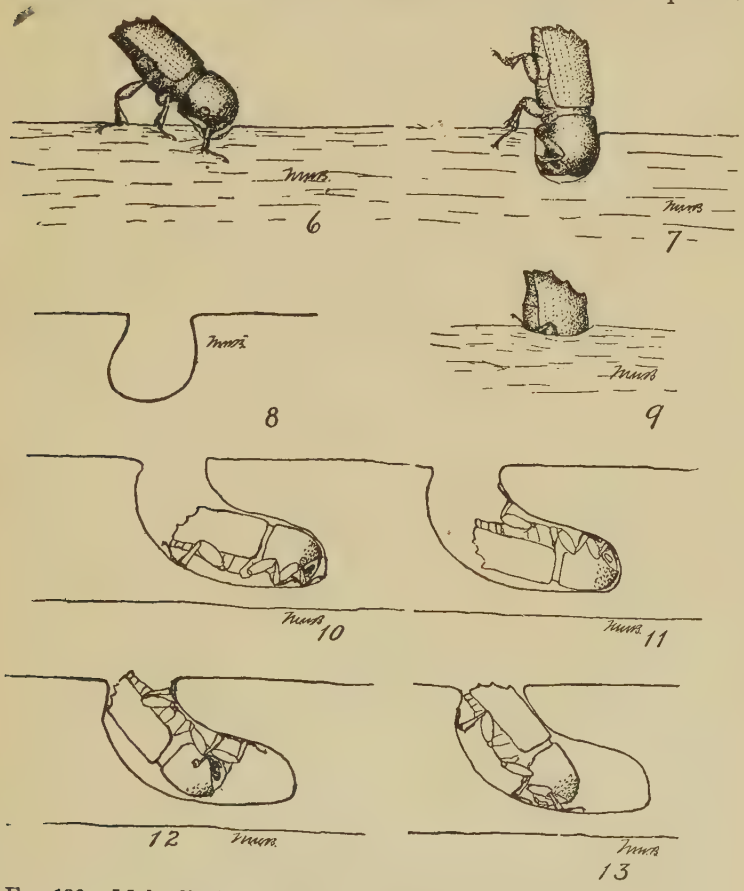


FIG. 136.—Male digging entrance tunnel in bark. (From Blackman.)

He is a polygamist, having 2 or 3 and sometimes as many as 8 wives, and he works hard often risking his life to make a home for them. In fact the superabundance of females is due to a large proportion of the

males losing their lives in attempting to construct homes. In starting a home, the male must cut an entrance hole through the bark of the host plant and hollow out a small chamber beneath the bark in which to receive the females which decide to take up their abode with him. In cutting through the bark he is exposed for a long time to birds and other predaceous enemies. After getting beneath the bark he may be so unfortunate as to bore into a pitch duct and have his burrow flooded with pitch.

Quite often the beetles attack living white pines which are unhealthy but which still contain a considerable amount of liquid pitch. Blackman selected several such trees containing burrows of the beetles. Many of these burrows had tapped pitch ducts and in some the male beetle had been able to dig only its length before being overcome by the pitch. Blackman's description of the trials of a male follows:

"Burrows were found in which only the end of the abdomen was visible, the rest of the beetle's body being in the hole surrounded by pitch. The most pitchy of these was chosen for study. When it was placed upon the stage of the binocular microscope and the light condensed upon it, the pitch flowed even more freely than before, completely enveloping the body of the beetle. He backed part way out of the entrance and tried to free his body of the sticky liquid by violent movements of the legs and abdomen, at the same time opening and closing the space between elytra and abdomen in an apparent endeavor to get air. For ten minutes he continued to work in his burrow covered with liquid pitch with only the end of his abdomen and elytra protruding and even these were often submerged momentarily. At

the end of this time he backed out with only his head in the burrow and his body nearly parallel to the bark and kicked violently, trying to force the sticky pitch to one side. As the burrow was still full he backed entirely out and plunged violently back into it, repeating this a number of times. The hardening resin was forming a bank about the entrance, making the burrow deeper and rendering it impossible for him to get to the bottom of the burrow without the body being completely submerged. After trying several times to resume work and being submerged each time, he backed entirely out of the hole and with his forelegs grasping the margin of the entrance, he sidled about halfway round the hole and in this way spread the adhering pitch to a distance of several millimeters.

"However, the burrow was still full of pitch and the specimen after trying in vain to resume work, again backed out of the hole and leaving it entirely, sidled off kicking violently. He proceeded for a distance of 6 mm. spreading the pitch as he went, and then turned toward the burrow again. After examining the brink carefully, he plunged in until only the end of the elytra protruded from the liquid resin. Apparently by trying several methods he had succeeded in disposing of enough of the pitch so that the end of his abdomen would remain unsubmerged and he could resume work. On the following day the burrow was still occupied but was little if any deeper than when last seen. All of the worker's efforts seemed to be needed in keeping the hole from closing, with his body, and in arranging the hardening pitch into a "chimney" around the entrance. Four days later the burrow had been carried no deeper and the

specimen was found dead in the hole embedded in hardened pitch."

After having successfully completed an entrance tunnel the male makes, at the inner end of the tunnel, a broad, flat, irregular chamber between the bark and wood. He eats the material as he excavates it and continues to make the chamber larger as he needs food. The size of his room depends on how long he is left alone. As soon as one or more females come to share the room, which we may call the reception hall, his activities are changed. He then spends most of his time guarding the entrance and removing the boring dust which the females kick out into the reception hall while making their egg tunnels.

Each female, after finding and entering the reception hall of a male, begins to construct a narrow tunnel leading out from the hall in a horizontal or oblique direction. When the tunnel is about as long as her body or a little longer, she backs out to the hall and the eggs in her ovaries are fertilized by the male. Then she hollows out a tiny hemispherical niche in the wall of her tunnel, boring it with her jaws and kicking the dust back between her legs into the reception hall. Next she backs out into the hall in order to turn around and having turned, she backs into the tunnel, feeling its walls until she finds the niche. From the tip of the abdomen a tiny, white oval egg $\frac{1}{50}$ inch long is thrust into the niche. Again she walks out to the hall, gathers a mouthful of fine dust, turns around and enters the tunnel head first. She packs the dust, mixed with a sticky secretion, about the egg until it is hidden in the niche.

Having completed the laying of one egg, she lengthens the tunnel far enough to make another niche and lay another egg in it. She may lay 2 or 3 eggs each day for

10 days before her strength fails and she dies. Usually her entire egg tunnel is an inch or two long and the eggs are placed alternately on the right and left sides of the tunnel. Each female starts her egg tunnel from a different point in the wall of the reception hall and a male with many wives will have tunnels extending in many directions from his hall. The tunnels must be separated by a considerable wall of bark and wood in order that sufficient room be left for the development of the larvæ, but quite often females do not space their egg tunnels properly.

Each larva upon hatching, eats its way through the egg shell on the side next to the bark and begins to eat the bark. By eating its way along in the inner bark it forms a tunnel, which is at first very narrow, but later, as the larva grows, the width of the tunnel increases. Much of the material in the bark is indigestible and passes through the digestive tract to fill up the tunnel behind the larva. The larval tunnel is usually directed away from the egg tunnel at nearly a right angle. Larval tunnels from egg tunnels which were placed too close together, often cross and recross each other, showing that the larvæ have attempted to find sufficient space by changing their directions. Many short tunnels also show that a large percentage of the larvæ do not succeed, but die before completing their growth.

Larval tunnels, when completed, vary from ¾ to 1½ inches long and are at first made entirely in the bark but later as the larvæ grow larger, their tunnels groove the sapwood also. The larva is a white, footless grub with a brown head and stout chewing jaws. It is only 1/12 inch long when full grown, 18 to 25 days after hatching from the egg. After its growth is completed the larva

ceases feeding and empties its intestine of bark and wood. It lies in the end of its burrow which is now largely in the sapwood and is slightly widened at the end to form a pupal chamber. Here pupation takes place in 5 or 6 days, in summer; then the newly formed beetle, still pale excepting its black jaws, begins to eat the wood ahead of it.

After feeding and thus continuing its larval tunnel for 2 or 3 days, the beetle bores through to the outer bark and makes a tiny opening through the surface. Here it receives a fresh air supply and casts out the refuse from its tunnel. Its color soon deepens to black and it continues to feed, making an irregular burrow in the bark for a week or so. Then it cuts a round exit hole and emerges to find fresh pine in which to feed, for the old home is getting too dry. After spending several weeks cutting irregular feeding burrows wherever it can find a break in the bark, it is ready to begin the construction of a new home. If a male, it will construct a reception hall; and if a female, it will seek a reception hall which some male has constructed.

The beetles do not all emerge at the same time but come out irregularly over a period of several weeks and consequently the generations are irregular. When winter comes the majority of individuals are newly formed beetles which remain in their old homes until the following April and early May before emerging to start new homes. Their young become mature in July about 2½ months after the homes were started. Those which mature early in July bring forth another brood of beetles in September while those which mature late in July do not produce another brood of beetles until the next spring. The beetles which emerge in September also

produce a brood of beetles the next spring but these must pass the winter as larvæ. Therefore two complete generations and a partial third generation are completed each year. This applies to New York and it is probable that longer growing seasons farther South insure the completion of three or more generations.

A study of the engravings made on the surface of the wood reveals a record of many of the hidden activities of the bark beetles. These engravings show such facts as how many wives a male had, how many eggs each female laid, how many larvæ hatched, how much each larva ate, and whether it matured and left the family burrows.

References:

Blackman, M. W. N. Y. St. Col. Forestry, Tech. Pub. 2, 1915.
Swaine, J. M. Canad. Dept. Agr. Ent. Branch, Bul. 14, 1918.

Weevils

Example: **The Rice Weevil** (*Calendra oryzæ* Linn.). Family, *Curculionidæ*.

Since the time when man first began to till the soil and to store grain for future use, he has been forced to share his stores with weevils. Written records of the ravages of weevils have been found dating from hundreds of years B. C. and throughout the world wherever grain is stored the weevils are present. The name "weevil" is an old Anglo-Saxon word, but the same insects attracted attention outside of England and were given common names in other languages. The Germans called them "Kornwurm," and the French "charançon."

There are several species of weevils which attack grain but one of the most common and widely distributed is

the Rice Weevil. It is called Rice Weevil because early students of its habits found it breeding in rice, and supposed it to have been shipped into Europe from India in stores of rice. No matter where it came from the species is now found breeding in the seeds of wheat, corn, oats, millet, barley, rye, buckwheat, acorns and even in old cotton bolls, as well as in rice.

Since its food supply is constant throughout the year, and its activities are not confined to temporary growing periods of its food plants, the weevil continues to breed, generation after generation, throughout the year in warm climates, such as our southern states. In climates where long periods of freezing weather occur, the activities of the weevil stop during such periods and all stages of the insect remain dormant until warmer temperatures arrive. Even moderately cool weather slows down the insects' development somewhat. Consequently the weevil is a much greater pest in warm climates than in cool ones. In the southern states the weevil not only breeds in stored grains of all kinds, but it flies to the cornfields and attacks corn as soon as it has reached the roasting-ear stage. In the central states, such as Kansas, the weevil does not attack growing corn or other grain, but will attack wheat in the shock or stack if threshing is long delayed. In northern states only grain in storage suffers from its attack.

The adult weevil is a small, hard, brown beetle, 1/8 inch or less in length, and it has four lighter reddish spots on the back. The front of the head is elongated into a snout. (Fig. 137.) This snout or beak is characteristic of members of the family *Curculionidæ* which is called the snout-beetle family. On the end of the snout there are small chewing jaws and like other beetles the mem-

bers of this family chew solid food. On the sides of the snout, a pair of elbowed antennæ with clubs on their tips arise. The thorax is densely covered with tiny, round pits, and the upper wings and legs are somewhat pitted also. The long snout is a great advantage to these insects for it enables them to bore a small hole through hard seed coats and reach much of the stored food within seeds with a minimum of labor.

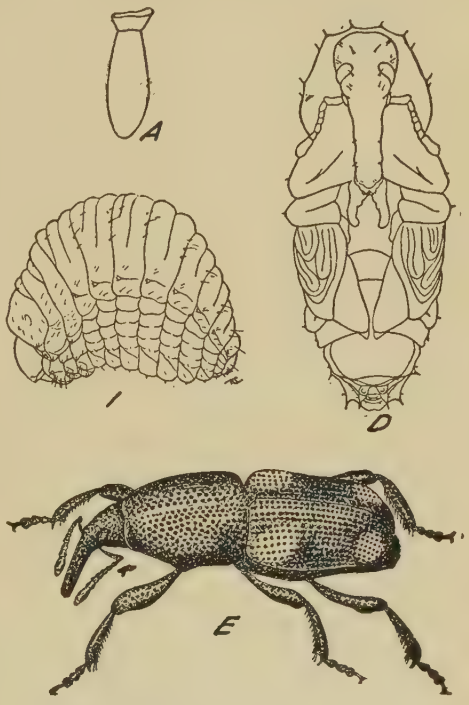


Fig. 137.—*Calendra oryzæ;* egg, larva, pupa, adult. (From Cotton, Jour. Agr. Res.)

Adult weevils eat abundantly and may remain alive for 6 or 8 months if they are supplied frequently with food. In cool weather, when their activities are slower, they can live as long as a month between meals but in warm weather they die soon without food. The adults will eat a great variety of plant products in addition to seeds. They are known to eat tobacco, peaches, grapes, apples, mulberries, potatoes, and it seems probable that they will eat most kinds of ripe fruits or wild berries. With

such an adaptable appetite and wings it is seldom that the adults starve. When suddenly approached or disturbed they have the curious habit of "playing possum." They fall over as if dead and draw all the appendages up close to the body. Soon afterwards they walk off as active as ever.

Although the adult weevils feed upon a great variety of foods their larvæ are restricted mainly to seeds, and since a larva completes its entire development within a single seed, they are limited to seeds containing sufficient food for their development. They are known to live successfully in rice, wheat, corn, hulled oats, millet, barley, rye, buckwheat, chickpeas, Job's tears, acorns and old cotton bolls. They cannot live in ground grains.

The females, after mating, deposit their eggs one at a time in holes drilled into seeds. A female in preparing to oviposit makes a hole with her powerful, slender beak, oscillating her body in such a manner as to give a combined up and down and rotating motion to the beak. The tiny jaws at the tip grind away at the hard kernel until a hole the length of the beak is excavated. She then withdraws the beak and turning around, finds the hole with the tip of the abdomen. An egg passes into the cavity, and accompanying it is a mass of gelatinous cement which fills up the cavity completely, forming a protective cap to the egg. In hard stored seeds, the operation of preparing an egg cavity requires a couple hours of hard labor and 3 or 4 eggs per day are all that a weevil can lay. However, she keeps this up for several months and may lay 400 or 500 eggs before her death.

The egg is white, elongate, pear shaped with a narrow neck at the top on which the cap of cement fits, and is

about 1/50 inch long. In warm weather it hatches in 4 or 5 days, but in colder weather or in the northern states it may require 10 days or more to develop. The larva which eats its way out of the egg shell is a fat, white grub without legs, but with a small, brown head and dark mandibles. It is only 1/8 inch long when full grown and spends its entire life buried within the seed. As the grub eats the interior of the seed, it tunnels through it and packs the undigested particles behind it, always keeping enough clear space about its body to turn around in. If it be disturbed, the grub will turn its head toward the disturber, gnashing its jaws.

When fully grown, the grub uses the end of its burrow for a pupal chamber. In preparing the chamber it covers all thin walls or weak places with a layer of cement made from its secretion and waste material, until a hard wall is secured. After this is completed, the larva becomes sluggish and, unlike most insect larvæ before pupation, it now lengthens out, losing its plump appearance. Then the skin is shed and uncovers the pupa. The pupa is at first white, but on the day before the adult is formed, the color darkens. Like other beetle pupæ it has the appendages free. The pupal period is about 5 days in warm weather and the larval period is about 20 days.

The adult remains in its pupal chamber several days before eating its way out of the seed. In cool weather it may remain inside the seed feeding for a month or more before emerging. A complete generation may be completed each month in summer in the southern states. In Florida there are seven generations a year, six between April 1 and November 30, and one between December 1 and March 31. The generations in any locality overlap so that young adults may be depositing eggs along with

their grandparents and beetles may emerge any day of the year.

REFERENCES:

COTTON, RICHARD T. Jour. Agr. Res., Vol. XX, p. 409, 1920.
HINDS, W. E., and TURNER, W. F. *Jour. Econ. Ent.*, Vol. IV, p. 230, 1911.

The seven species of beetles which we have discussed are but seven drops in the bucket, and the bucketful in *Coleoptera* is 195,000 species. We can only mention a few of the more conspicuous families of the remaining species in order to give a more comprehensive idea of this gigantic order. The "**ground-beetles,**" of which we have studied one example, include over 17,000 species and they are very important to us because nearly all of them in both larval and adult stages devour other insects. A closely related family, the "**tiger-beetles,**" also destroys insects and the tiger-beetles are noted for their rapid and fearless attacks upon large insects. They differ from ground-beetles in preferring to carry on their activities in bright sunlight and on open ground.

Other groups of predaceous beetles are found in the water. The "**diving-beetles**" will devour such small animals encountered in streams or ponds as worms, insects, tadpoles, molluscs and small fishes. "**Whirligig beetles**" are surface swimmers and often occur in groups on quiet water, where they capture smaller insects and other animals. Most of us are familiar with their habit of circling rapidly about on the water.

The "**carrion-beetles**" are interesting because of the art with which some of them perform the duties of sextons. Upon discovering a dead sparrow, mouse, or other small animal these beetles dig beneath it, removing the

earth so that the corpse falls into the hole; then the earth is replaced and the female beetle deposits her eggs on the corpse so that her young may use it for food. There are many other smaller members of this family which devour carrion, or fungi, or living insects without taking the trouble of burying them.

"Rove-beetles" are often found with carrion-beetles and other insects about dead animals or other decaying matter, but seem to be there most commonly for the purpose of preying upon the living insects such as fly maggots. These little beetles also have the curious habit of curling up the rear end as if threatening to use a sting, which, however, they do not possess.

"Fire-flies" and "glow-worms" are beetles of the family *Lampyridæ*. Not only the adult beetles, but their larvæ and in some cases eggs and pupæ also, possess the power of producing the well known greenish light which enlivens our summer nights. Fire-flies are night fliers and remain hidden away from the bright light of day as though they would not have the sun outshine them. The adults of some species at least take little or no food but the larvæ feed upon slugs, snails or other small animals. Fire-flies and also the family to be mentioned next are sometimes not recognized as beetles because the upper wings are flexible and not so hard as those of other beetles.

"Blister-beetles" are so called because their bodies when dried, pulverized and made into a paste have been used in medicine to produce a blistering effect on human skin. But, to entomologists they are especially interesting because of their peculiar larvæ. Upon hatching from the egg the larva resembles the young of a lace-wing; upon molting it sheds the long legs and comes to resemble

a ground-beetle larva; later it assumes the entirely different form of a fat white grub. The young larvæ of the first form must be very active in locating the egg pods of grasshoppers, the nests of bees, etc., in which their food is located; the older larvæ can lie still and grow fat on eggs and honey. This type of metamorphosis in which there are several distinct larval stages is called *hypermetamorphosis*.

Another group of beetles which attracts the notice of the average boy is the **"click-beetle"** family. These slender, hard-shelled beetles have a flexible joint between the first and second segments of the thorax, and by suddenly bending this joint they produce a clicking sound. When a beetle falls on its back a few clicks enable it to throw itself into the air and turn over. The slender, hard-shelled larvæ are called "wire-worms" and are much disliked by the farmer, for they eat the roots of grasses and of crops which are planted on land formerly in grass. There are larvæ resembling wire-worms, but called **"meal-worms,"** which live in granaries, mills and in scattered grain on dry barn floors, but the meal-worms belong to another family, *Tenebrionidæ*.

One family of small beetles, the **Dermestidae,** is well known to all who keep mounted specimens of insects or other animals either in museums or at home. Several species of this family devour parts of the dried skins or bodies of specimens and often ruin the entire mount. Other species sometimes annoy the storekeeper and housewife by invading the pantry and sampling the ham, bacon, or cheese. Another species, called the carpet-beetle, ate holes in woollen carpets until the vacuum cleaner nearly eliminated it; now it is found to eat holes in woollen clothing which remains undisturbed for some months.

Most children during nursery days learn about **"lady-bugs,"** and every adult should know that "lady-bugs" are beetles. These small, oval, red and black spotted insects eat large quantities of aphids and the beetles as well as their larvæ may be found crawling about over foliage seeking aphid colonies. A few species, black sheep of the family, have the habit of eating foliage of squash, bean, etc., instead of aphids.

The family **Chrysomelidae,** to which the striped cucumber-beetle belongs, contains many injurious insects which devour the leaves of plants and often in the larval stage attack the roots. The yellow and black striped potato beetles, corn root-worms, flea beetles, elm leaf beetles and numerous other pests belong in this group.

Another group of pests which should be mentioned before leaving the beetles is the **"weevils"** or "curculios," of which the rice-weevil was our example. This family of over 25,000 species constitutes probably the largest family of the animal kingdom. Their characteristic long snouts enable them "to nose into everything." They are not content with the outer covering but thrust their snouts into the interior of fruits, nuts, seed pods, blossoms, buds or stems of plants to find their food. The females often use their snouts to drill holes in which to deposit eggs. The larvæ are usually soft white grubs living inside fruit, seeds, buds, or some other nutritious parts of the host plant. The larvæ of some species, such as the alfalfa and clover leaf weevils, live outside and devour the foliage.

References:

Comstock, J. H. *Introduction to Entomology,* Chap. XXIII, 1924.
Imms, A. D. *General Textbook of Entomology,* pp. 456-516, 1925.

CHAPTER XXIV

ORDER STREPSIPTERA

(Gr. strepsis, a turning; pteron, wing)

The members of this order are tiny parasites living within other insects. Only males have wings; the minute fore wings are club-like and are not used for flying; the broad, fan-shaped hind wings are folded or twisted into plaits when at rest on the back. Adult females are legless grubs and do not leave the body of the host.

Strepsiptera are called the twisted-wing parasites, probably because the hind wings, when folded on the back, are not covered by the fore wings and thus present an appearance unique among insects. It is a very small order of about 150 species and none of them are commonly seen. They are very small and live nearly the whole lifetime within the bodies of other insects such as bees, wasps and leaf-hoppers. The males on completing the pupal stage leave their hosts and can fly, but the females have no pupal stage and remain until death within the last larval skin which covers them in the body of the host.

As many as 2,000 young larvæ are hatched within the abdomen of the female and these make their way to the outside world where they crawl about over the host and surrounding objects. The young larvæ have legs and are quite active. The majority of them probably die of starvation, but the successful ones find their way to larvæ of their appropriate host insects. This may be done by crawling upon bees or wasps in flowers and being

carried home, or by chance finding of leaf-hoppers, while wandering over plants. Having once found the right kind of host larva, the tiny twisted-wing larva bores in at once and lives the rest of its larval life as a parasite within the body of its victim. At the first molt the parasite loses its legs and becomes inactive. It is fed by the blood of its host which continues to grow and change into an adult. The parasitized host insect, however, gradually grows weaker and is unable to reproduce young.

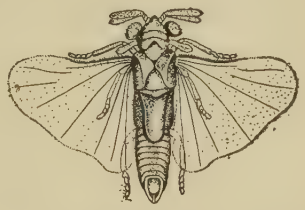


FIG. 138.—Male of a twisted-wing insect. (From Comstock, after Pierce.)

The presence of *Strepsiptera* in a wasp or other host may be often detected by distortions of its abdomen; the parasites as they become nearly grown push their heads out between the chitinous rings of the abdomen, thus causing a hump to appear.

REFERENCES:

PIERCE, W. D. U. S. Nat. Mus. Bul. 66, 1909.

COMSTOCK, J. H. *Introduction to Entomology*, Chap. XXIV, 1924.

CHAPTER XXV

ORDER HYMENOPTERA

(Gr. Hymen, a membrane; ptera, wings)

The members of this order have, in the adult stage, either two pairs of wings or none. Wings when present are thin, usually clear, with a few veins. Hind wings are smaller than front ones and they are joined together so as to seem like one pair when in flight. Wingless forms have a very narrow waist at the front end of the abdomen. Chewing jaws are present and in some families there is also a tongue for lapping liquids. The larvæ resemble grubs, maggots and caterpillars.

Ants, bees, and wasps are the most commonly known members of the order but a large number of species consists of small insects seldom noticed except by entomologists. Most all of them are active only in daylight but many stay in the shade of trees or other plants. They vary greatly in size, shape and habits. *Hymenoptera* differ from other insects in having the fore and hind wings united by a row of tiny hooks so that the two wings can be used as one broad wing in flight, but separated and placed one on top of the other when the insect crawls into a crevice.

The order is divided into two main groups. One group has a narrow waist and the other a broad waist like that of most other insects. The broad-waisted group includes "sawflies" and "horntails." The larvæ of "sawflies" eat the leaves of plants and often resemble caterpillars but can be distinguished from them by the eye spot on the side of the head which caterpillars lack. Some

sawfly larvæ such as the cherry and pear slug are covered with a coat of slime and resemble slugs. Adult female sawflies have concealed beneath the abdomen a set of saw-like ovipositors which are in most species used to cut slits in plants for egg laying. Horntail females (Fig. 139) have long, stout ovipositors which project from the rear

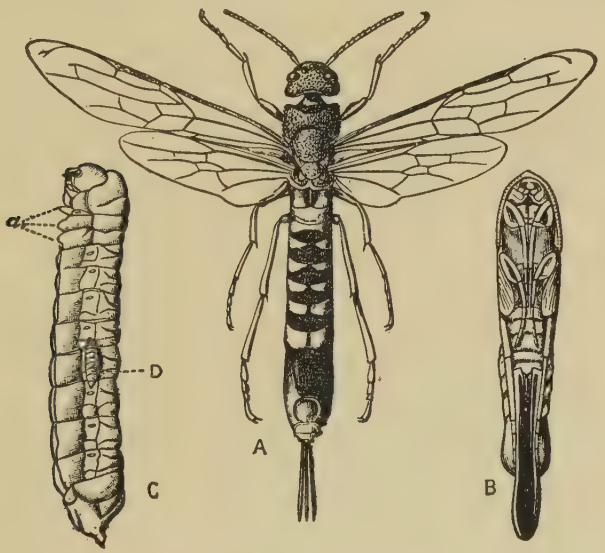


Fig. 139.—Horntail: *A*, adult; *C*, larva; *B*, pupa; *D*, parasite larva. (From Sharp.)

of the body and are used for placing the eggs beneath the bark of trees. Their larvæ are white, footless grubs which bore into the wood of trees.

The narrow-waisted group consists of gall-wasps, insect parasites, wasps, bees and ants. Gall-wasps are small insects with the abdomen flattened from side to side. The larvæ are tiny, legless grubs usually living in plant galls. Insect parasites form a group of thousands of

species whose larvæ live within the bodies of other insects and destroy them. There are forms which parasitize eggs, larvæ, pupæ and adults of all orders of insects. Some of the tiniest species which complete their entire growth and transformation within the egg of another insect are but $\frac{1}{50}$ inch long. Some species are beneficial to us because they parasitize our insect pests. Other species are harmful because they parasitize the parasites and are known as secondary parasites. Species which parasitize the secondary parasites are beneficial and are known as tertiary parasites.

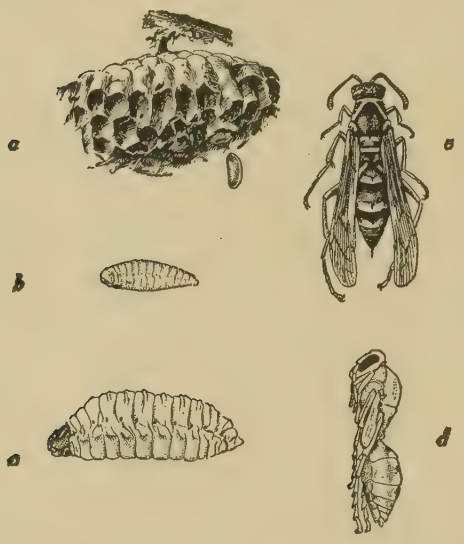


FIG. 140.—A common wasp, *Polistes: a,* nest with egg; *b,* young larva; *c,* older larva; *d,* pupa; *e,* adult. (From Kellogg.)

Wasps (Fig. 140) are known to us best because of their stings. Stings are modified ovipositors and are therefore only possessed by females. They use their chewing jaws and feet to construct cells either in the ground, in stems of plants, in nests of mud or of wood pulp and within these cells their larvæ are reared. The sting is used to paralyze other insects or spiders which are then placed in the cells as food for the larvæ. Mud-daubers, yellow-jackets and hornets are common species of wasps. Most species are

solitary, each female constructing a place for her young apart from all others. A few species like the hornets, are social, a number of females coöperating in building a single large nest in which to rear their young together. Any animal which attempts to injure the nest of a wasp or to injure the wasp herself, may expect her to use the sting as a means of defense.

Fig. 141.—Nest of bumblebee: ground cut away to show nest cavity and wax cells. (From Kellogg.)

Bees are best known for their honey and stings. Only females possess stings and very few species store any quantity of honey. Bees are easily distinguished from other insects by their hairy bodies and broad, flat hind legs. The hairs and flat basal joint of the hind tarsus are useful in gathering pollen from flowers and in carrying it to the nest. Many bees also gather nectar from the bases of flowers by means of a long, lapping tongue. Most bees make cells either in the ground, in hollow stems of plants or in wood and within these cells their larvæ are reared. Pollen and nectar are stored

in each cell as food for the larva. A few bees like the honey bees and bumble bees (Fig. 141) make cells of wax, a product from wax glands in their bodies, but most species of bees make their cells of wood, leaves or earth. A few species make no cells but steal into the nests of other bees to lay their eggs like cuckoos. Most bees are solitary, building their nests apart, but a considerable number of species live a social life in colonies where there is more or less division of labor. Probably the culmination of social life among bees is found in the domesticated honey bee, *Apis mellifera* Linn., which forms organized colonies consisting occasionally of as many as 100,000 individuals. Several other species of the genus *Apis* form quite large colonies also.

Ants in many ways seem to be the highest peak of development among invertebrate animals, much as we consider man the highest among vertebrates. In both ants and man it is not the high degree of specialization of parts of the body for a certain purpose which makes them outstanding animals, for many others have more highly specialized parts, but it is the general adaptability enabling them to successfully meet a wide range of circumstances which makes them the chief animals.

Ants inhabit all parts of all continents of the world where terrestrial life can exist, and they are usually the most numerous animals in any one locality. Worker ants are known to live from 4 to 7 years, queens from 13 to 15 years and their colonies are said to sometimes outlast a generation of men. Such stability is not found among other insects. Other groups of social insects which might be considered as most highly developed insects are handicapped in their struggle for existence by a restricted

diet or by the use of expensive building materials such as wax and wood pulp. Ants are practically omnivorous and require no building materials except the earth in order to build structures which will contain colonies of thousands of individuals. The young of ants although fed and protected by the adults, are not enclosed in cells to remain until mature like bee larvæ, but are carried from chamber to chamber where conditions of temperature and moisture suit them best at different stages of development.

Ants are also unique in their relations with plants and other insects. Some species of ants gather seeds of grasses and weeds and store them in underground chambers for food. Others cut off leaves, carry them to galleries below the surface and shred them to form a green manure on which the spores of certain fungi are scattered. The fungi grow only on this manure and the ants make the fungi their food. Other species of ants care for colonies of aphids and use as food the honey dew produced by the aphids. A few species enslave other species of ants which will work for their captors.

The relations between men and ants are usually peaceful because they usually let each other alone. Men and ants can both become abundant in a locality without greatly inconveniencing each other except in the case of a few species, such as the Argentine ant in our southern states and the little house ants. Most ants are not troublesome to us because they live in the ground and eat waste materials rather than our possessions.

Worker ants are wingless. Males and queens are usually winged during the mating season. Mating takes place during a flight in which the species become widely

distributed. After this one flight the queens remove their wings either by rubbing them off or biting them off and the males soon die. Ants may be distinguished from other insects by the formation of the narrow waist. This segment has on it a knot or scale-like enlargement which is quite conspicuous. On this knot is located a file-like organ which gives out a series of vibrations by means of which ants communicate with each other. Most ants have no sting but bite with their mandibles and some by bending the tip of the abdomen forward squirt formic acid into the wound.

Leaf-eaters

Example: **The Currant Worm** (*Pteronidea ribesi* Scop.). Family, *Tenthredinidæ*.

Any one who has grown either red or white currants or gooseberries, has probably made the acquaintance of green and black spotted larvæ which eat the leaves of these bushes, working together in colonies of six or ten or more on a leaf. They are commonly called "currant worms" and many entomologists have called this species the "Imported Currant Worm" since it is not a native of America but was imported accidentally on nursery stock about 1857 from Europe. It has become so widely distributed and common throughout the northern United States and Canada that the name "Imported" seems no longer appropriate.

Adults of the Currant Worm are, like other members of the family *Tenthredinidæ*, known as sawflies. They are not true flies but are members of the order *Hymenoptera* and have two pairs of wings. They differ quite decidedly from the wasps, bees and ants by having a broad

joint between thorax and abdomen instead of the narrow waist. The wings have an extensive venation and there is a black, stout front margin on the fore wing. The female is about ⅓ inch long with black spots on top of the thorax and a yellowish abdomen. (Fig. 142.) The male is smaller, about ¼ inch long, and has most of the abdomen black.

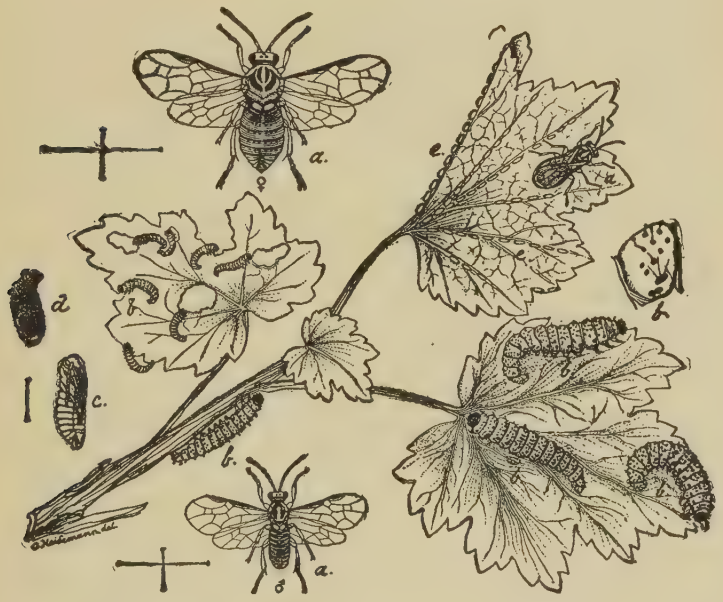


Fig. 142.—Currant worm: *a*, male and female sawfly; *b*, larvæ; *c*, pupa; *d*, cocoon; *e*, eggs. (From Washburn, after Lugger.)

The adult sawflies emerge from cocoons on the ground in April when the gooseberry leaves are unfolding. After mating, the females are ready to begin egg laying within an hour or so, and they deposit the eggs end to end in rows on the underside of the leaf ribs. The eggs are glued to the ribs of the leaf and not inserted into slits in the

ribs as is usually the case with sawflies. In fact, the females of this species have rudimentary saws. Like all female sawflies, they have a pair of saws, but these consist of the blades minus the sharp teeth.

The eggs are elongate, smooth, white, about $\frac{1}{20}$ inch long, and a line of them appears like a small, white chain on the underside of the leaf. They are usually laid on leaves in the central or lower portions of the bush. The eggs hatch after a week or ten days, and small whitish larvæ emerge from them. The larvæ begin at once to eat small holes through the leaves and the food changes their color to green. In a few days the skin is molted and the larva now has a black head and many black spots over its green body. In general shape it is much like a caterpillar but may be distinguished by its habit of curling the rear end of the body under, by its simple eye on each side of the head and by the number of prolegs. It has seven pairs of prolegs while caterpillars have five or less.

While small, the larvæ live together in colonies on a leaf. After they have consumed the entire leaf they scatter to other leaves to feed. They are usually nearly grown and have already eaten a considerable part of the foliage before the larvæ appear on the top leaves where they become conspicuous. The gardener who would "get them" early must therefore watch the lower leaves of his bushes. When nearly full grown the larva sheds the black-spotted skin and becomes entirely green except the black eye-spots. It is now about $\frac{3}{4}$ inch long and 2 or 3 weeks old. Very soon after assuming the green coat, the larva descends to some dark, sheltered position near the bush, usually under fallen leaves or rubbish on the ground, and spins a cocoon. Sometimes the cocoons are attached to the stems or leaves of bushes a foot or two above

ground and sometimes the cocoons are found below the surface of the soil.

The cocoon is an oval brown silken one, spun from the glandular secretion which issues through the lower lip of the larva. The strands of silk flow together and form a continuous parchment-like surface rather than separate threads. Activity within the cocoon varies greatly with different individuals and the causes of such variations are not yet known. Some larvæ transform to pupæ within a few days after enclosing themselves in cocoons, while others wait weeks or months before doing so. The pupal period also varies greatly in length. Some adults emerge to lay eggs for the second generation late in June while others do not emerge until July, August or in some cases not until the next April. Consequently the broods become very irregular and any stage of the insect may be found during a large part of the summer. It is believed that there are in addition to the one complete spring brood, two partial summer broods in the extreme northern states and Canada. Winter is passed in the cocoon in the larval stage.

The females of this species, especially those emerging from second and third generations, very commonly do not mate with a male but lay large numbers of unfertilized eggs. These eggs hatch normally but Cæsar and Garlick found that the sawflies which matured from them were invariably males. Other workers in Europe have found an occasional female among them. The larvæ from unfertilized eggs seldom do much damage for many of them die soon after hatching.

Like its host plants, the Currant Worm prefers cool climates and the larvæ die if they fall or crawl upon soil which is heated and dried by a midsummer sun.

Spring is the season best suited to their development. Black currant bushes are immune to their attacks but red currents, white currants and gooseberries are readily eaten.

REFERENCES:

LUGGER, OTTO. Minn. Agr. Exp. Sta. Bul. 43, 1895.
CAESAR, L., and GARLICK, G. *Canad. Ent.*, Vol. 52, p. 106, 1920.

GALL-MAKERS

Example: **The Oak Hedgehog Gall-maker** (*Acraspis erinacei* Beut.). Family, *Cynipidæ*.

The leaves of white oak trees, in the eastern half of the United States and Canada, are commonly ornamented with small yellowish galls which arise from the main veins of the leaf. The galls are round or oblong, and have a pebbled surface from which numerous hairs arise. (Fig. 143.) The appearance of the galls suggests the hedgehog and hence their common name. The galls begin to appear as very small outgrowths from the leaf veins in June and reach their full size late in August when they measure from ½ to ¾ inch across. If you cut into a young gall you will find it easily halved, but an old gall is quite hard and resistant to the knife. When the gall has completed its growth, the inner layers of tissue which were formerly

FIG. 143. — Oak Hedgehog Gall: *a*, gall on oak leaf; *b*, cross section of gall (From Beutenmuller.)

soft and green, have become very hard and yellow. Inside the gall (Fig. 143) there are several small round rooms, the number of rooms varying from 2 to 8 in different galls of this species.

If the gall has been punctured, and there is an opening through its surface, you will probably find the interior uninhabited, unless some tramp insect has crawled in for a nap. The punctures may have been made by birds seeking the insects within the galls, or the little wasps may have gnawed their way out. If there is no hole in the surface of the gall, you will usually find one or more small, white maggots, or pupæ, or tiny wasps, in the rooms.

In November there emerges from these galls, a race of queer little brown insects, varying in length from $\frac{1}{16}$ to $\frac{1}{8}$ inch, with patches of hairs on the head and abdomen. They have two pairs of wings but the wings are tiny, useless remnants and the insects must walk in order to change location. Every individual is a female and armed with a long needle-like ovipositor extending along the lower side of the abdomen, from base to tip. No males exist in the autumn generation of *Acraspis erinacei*. The females unlike most insects, are active only on cold days or in early morning when the temperature is well below 60°. When it is warmer they remain quietly resting in crevices of the bark or about the buds. During periods of activity they walk about on the twigs of the white oak, seeking the buds in which next year's leaves and flowers are folded away. Upon finding a bud the insect climbs on top of it and begins to use the ovipositor. First it is used to find the tips of the outer bud scales and lift these out of the way, then it is thrust down among the embryo leaves or flowers and an egg deposited there, attached to

an inner scale or leaf. The egg laying is completed by filling the entrance where the ovipositor entered the bud, with a waxy secretion from the reproductive glands. The insects continue egg-laying until a heavy frost kills them, usually in early December.

The eggs, which can only be seen through a microscope, are about $\frac{1}{63}$ inch long, white and provided with a slender stalk like the Lace-wing egg. They keep the species alive through the winter and hatch late in April or early in May when the tips of the buds begin to expand. The tiny larva cuts its way through the tip of the egg and makes its way to the base of the egg-stalk, where it enters the plant tissues by means of its sharp jaws. The bud scale or tip of the leaf bud, which the larva bores into, begins very soon to react to the invader by forming about it a small, round outgrowth from the surface. This outgrowth becomes a yellow or red, oval gall about $\frac{3}{16}$ inch long, with a pebbled surface. The wall of the gall is thin and it contains a single chamber in which the larva dwells.

The larva is a fat, white, wrinkled maggot with no legs, no distinct head, but a pair of tiny, sharp, pointed jaws. It remains with the abdomen bent until about full grown when the abdominal segments plump out and the body lies straight. It is then nearly $\frac{1}{8}$ inch long. The larva pupates within its chamber and the adult gnaws a door by which it can emerge from the gall. Adults appear late in May about two weeks after the eggs hatch.

The adults of this generation are shining black insects with fully developed wings. The abdomen is peculiarly short and high, while the head is bent downward. (Fig. 144.) There are distinct males and females, the males

being less than 1/16 inch long and females over 1/16 inch long. These insects fly about from tree to tree and mate. Then the females deposit their eggs in the main veins of the white oak leaves, always close to the food-carrying tubes in the veins. The eggs are quite similar to those

FIG. 144.—*Acraspis erinacei:* egg, larva and adult.

laid in November and are usually found in small groups of 2 to 6 embedded in the leaf tissues.

About the time when larvæ hatch from the eggs, late in June, the first signs of galls appear upon the leaf veins where each group of eggs was laid. At first these are merely slight swellings, but during July and August they continue to increase in size, forming the characteristic Oak Hedgehog Galls. They continue to grow only so long as the larvæ within are actively feeding. If the larva within a gall be destroyed by parasites or be removed, the gall will stop growing. It is not known

whether secretions from the larva or its movements within the plant tissues stimulate the extra growth around it. What causes each species of gall maker to produce a definite, characteristically shaped gall, different from those produced by other species, is also unknown. A single gall forms about each group of larvæ in such a way that each larva is in a separate round cell. Thus a gall contains as many compartments as there are larvæ in the group.

The larvæ of the summer generation are very similar to those of the spring generation in appearance, but grow much more slowly. The pupæ form within the larval compartments in September and the adults gnaw their way out by November.

Thus we have two generations of *Acraspis erinacei* Beut. per year. The first generation develops within small, single-compartment galls formed on buds of the white oak during May. The adults, which emerge about two weeks after the larval stage begins, are winged and of both sexes. The second generation develops within larger, several-compartment galls which are formed on the leaf-veins of the same kind of tree during June, July and August. The adults emerge in November four months after the larval stage begins, and are all females with a mere vestige of wings.

Although *Acraspis erinacei* is the only species of insect which produces the Oak Hedgehog Galls, it is not the only species found enclosed in those galls. There are several species of parasites of the family *Chalcididæ* which very commonly are found in the galls. The tiny wasps of these species deposit their eggs touching the eggs of the gall maker shortly after its eggs are deposited in the leaf veins in June. After the gall maker hatches

and begins to feed, the gall grows around it, enclosing the gall maker and the parasite egg together in a compartment. Soon the parasite egg hatches, its larva eats the plant food surrounding it, and grows faster than the gall maker. As soon as the gall maker molts its skin and while the body is still soft after the molting, it is devoured by the parasite larva.

If two or more parasite eggs happen to be in the same chamber, the larvæ from those eggs do not all survive. Only the strongest one survives to pupate and emerge from the gall. Adults of the first generation of parasites emerge about the end of July and deposit eggs in the galls for a second generation. The adults of the second generation emerge from the galls the next June.

Another species, *Synergus erinacei* Bass, of the family *Cynipidæ,* makes no gall of its own, but lays its eggs in the developing Oak Hedgehog Galls. The larva at first eats the gall tissue about it, thus forming another chamber in the gall. Later it bores through the partitions into other chambers within the gall and enters these chambers one by one to eat the gall makers or parasites which happen to occupy them. Having obtained all the animal food it desires, or having exhausted the supply, it completes its growth at the expense of gall tissue and transforms within the gall. There is a second generation of this species also.

Galls produced by members of the family *Cynipidæ* are usually found on various species of oaks although a few are found on rose. There are more than 350 kinds of Cynipid galls on oaks in North America alone. Some of the galls known as "oak apples" become several inches in diameter. Galls are not usually of great economic importance. They may check the growth of a tree some-

what and be unsightly, but they seldom do any serious injury before parasites check their increase.

REFERENCES:
TRIGGERSON, C. J. *Annals Ent. Soc. Amer.*, Vol. 7, p. 1, 1914.
FELT, E. P. N. Y. State Mus. Bul. 200, p. 94, 1918.

PARASITES

Example 1. **The Militant Noctuid Parasite** (*Apanteles militaris* Walsh). Family, *Braconidæ.*

Caterpillars of many species, in the family *Noctuidæ,* and especially of the Army-worm, Fall Army-worm and Corn earworm (or Bollworm as it is frequently called), are very often killed about the time they become full grown, by tiny parasitic insects of the species *Apanteles militaris* Walsh. The tiny females of this species lay enough eggs under the skin of each caterpillar to produce an army of miniature maggots within its body. About two weeks after the eggs were laid the maggots all bore holes through the body wall of their victim and come outside to spin their cocoons, all in a mass. The perforated caterpillar crawls a short distance away to die.

The adult parasite is about $\frac{1}{16}$ inch long, black, with yellowish legs, and a distinct black spot on the front margin of the fore wing. (Fig. 145.) The abdomen is very small in proportion to the large number of eggs contained in it. Each female is capable of producing probably 1,000 eggs, and she may lay as may as 72 eggs in one puncture of the victim's skin during less than one second of time. Such rapid egg laying is found only among parasitic insects and their success in life is dependent upon speed in this operation. They must strike

before their hosts, which are always much larger insects, can get away from them or brush them off.

The parasite apparently recognizes a proper host on touching it with the antennæ, following such recognition the ovipositor and abdomen are bent forward under the thorax and the sharp ovipositor is very quickly thrust into the caterpillar. Having done this, the parasite folds its wings together on its back and draws its legs up close

FIG. 145.—*Apanteles glomeratus: a,* adult; *b,* cocoon from which adult has escaped; *c,* adults emerging from cocoons, natural size. (From Chittenden, U.S.D.A.)

to the body, holding itself in position only by its ovipositor. This contraction of the appendages is a precaution against the attacks of the caterpillar's jaws, for during the oviposition the caterpillar may throw itself about violently in an attempt to dislodge the parasite or bend the head around and bite at her. After remaining in this position for an instant, during which time many eggs are pumped into the host, the parasite unfolds her appendages and darts away. Sometimes she will not succeed in placing enough eggs in one puncture, so she

makes several before leaving the host. If the caterpillar is nearly full grown she may run along its back, jabbing continually with the ovipositor but never succeeding in puncturing the skin, for its covering of chitin is too thick to be penetrated. She can only succeed in parasitizing larvæ which have not yet entered the last larval stage (sixth instar).

The oval, white egg is about $\frac{1}{300}$ inch long when first laid in the tissues of the caterpillar, but absorbs enough material from its surroundings to increase its size considerably before hatching, when it measures $\frac{1}{36}$ inch long. The egg stage lasts about 5 days. Upon hatching the tiny larva escapes into the body cavity of its host and feeds upon the fat cells and blood of the host. Within a single caterpillar there may be from 50 to 100 or more parasitic larvæ, one from each egg that was deposited.

The body of the parasite larva is very peculiarly fitted for its mode of life. Since it lives in the blood of its host, it is unable to breathe air into spiracles, and since the host's blood contains digested food, the larva needs only to swallow the blood and then eliminate the excess liquid from its body in order to be nourished. Consequently the larva has no spiracles or external openings to its tracheæ, and it has no connecting passage between stomach and anus. Instead, it possesses a large membranous pouch called the caudal vesicle (Fig. 146 cv.), which extends out beyond the rear end of the body. The caudal vesicle has a very thin wall through which oxygen from the host's blood is absorbed by osmosis and carbon dioxide given off. An

FIG. 146. — *Apanteles militaris:* Young larva, *CV*, caudal vesicle. (From Tower, *Jour Agr. Res.*)

extension from the heart tube of the larva reaches back into the vesicle and all blood before entering the heart must first pass from the body cavity into the vesicle. Here the blood of the parasite larva in addition to receiving oxygen, eliminates its liquid waste through the vesicle wall into the host's blood. The host caterpillar then eliminates the waste products of its parasites along with its own, by means of its kidney-like tubes, called Malpighian vessels.

FIG. 147.—*Apanteles militaris:* mature larva, showing spiracles. (From Tower, *Jour. Agr. Res.*)

When the parasite larva is about ready to cease feeding and transform, its body undergoes a marked change. Spiracles appear along the sides of the body; the caudal vesicle is drawn into the anus and an intestine is formed to complete the alimentary canal, although this is not yet opened for the passage of solid wastes; the jaws become larger and sharper; and within the transparent body a pair of long coiled silk glands are formed, filling most of the body cavity. After all these changes are completed, about two weeks after the egg was laid, the parasite larva begins to molt its transparent skin and uncover its new structures. With its new jaws it slowly cuts through the muscles and skin of the host caterpillar. When an opening of sufficient size has been made, the larva squeezes through, but comes to a stop when about two-thirds of its body is outside the host, and begins to construct its cocoon.

Silk flows from the lower lip. The first few threads are attached to the lower side of the last segment of the larva which is outside of the caterpillar. After making

an attachment at this point the larva straightens out its body, then swings its head back again to attach another thread. It continues this process, bending below, to the side and above, until it is surrounded by loops of loose silk. Then the rear end of the body is pulled out of the caterpillar and the larva turns around to assume a reversed position in the partial cocoon. Soon its body is completely surrounded by loose threads which form an outer support for the closely woven cocoon which is to be spun within. Before making the latter, however, the larva usually works itself entirely free from the host and comes to rest on some adjoining object such as grass, stones or earth. Here the tough inner cocoon is completed.

During this process the parasitized caterpillar lies still as though paralyzed but by the time the cocoons are completed it usually recovers enough to crawl away before it dies. It should be noted that all of the 50 or more parasites within the caterpillar gnaw through at about the same time and construct their cocoons. Many of the cocoons become entangled by their loose outer threads and come to lie in a mass near the caterpillar.

The cocoons are a dirty white or light buff color, nearly ¼ inch long, and the larva within is pale green. About a day after leaving the host, the larva's intestine has opened and the accumulated solid waste is voided into the end of the cocoon. The next day the last larval skin is molted and pushed to the end of the cocoon to cover the waste. This molting uncovers the cream-colored pupa. The pupal stage lasts about 9 days during which the color of the pupa gradually darkens. When the adult is fully formed it sheds the pupal skin, cuts a round cap off the end of the cocoon with its jaws, and pushes up

this cap to climb out. (Fig. 145 b.) As soon as the adult is out of the cocoon it passes a quantity of waste, then expands and dries its wings.

The adults live for a week or more, feeding on drops of honey-dew or nectar from plants and usually the two sexes mate. Sometimes the females will lay their eggs without mating and as in the case of the currant worm the unfertilized eggs produce males.

There seem to be two generations of *Apanteles* each year corresponding to the two generations of the Army-worm. The host and parasite both seem to pass the winter in northern states as partly grown larvæ. In the south they may winter in the cocoons also.

Many investigators studying the habits of the hosts of *Apanteles militaris* have come upon the masses of tiny white cocoons in fields where the caterpillars had been living. The species is widely distributed over the United States and Canada and seems to be one of the important natural agencies for keeping the various Noctuid hosts from becoming exceedingly abundant. Like other insects, however, the little parasites have their optimum weather conditions and are more abundant in some seasons than in others. They require warm sunny days during the egg laying period in order to do their best work.

References:

Tower, D. G. *Jour. Agr. Res.*, Vol. 5, p. 495, 1915.

Muesebeck, C. F. W. Proc. U. S. Nat. Mus., Vol. 58, p. 536, 1920.

Parasites

Example 2. **The Gelechiid Stem-Gall Parasite** (*Copidosoma gelechiæ* How.). Family, *Chalcididæ*.

Among the Tineid moths is a large group which some authors call the family *Gelechiidæ*, while others call it

the sub-family *Gelechiinæ* of the family *Tineidæ*. One genus in the group is *Gnorimoschema* and this genus contains a number of species of small moths whose caterpillars live in the stems of various herbaceous plants, causing galls to form on the stems. *Gnorimoschema gallæsteriella* Kell. and *G. buskiella* Kearf. make galls on stems of asters, *G. heliopa* makes galls on stems of tobacco in India and South Africa, *G. gallæsolidaginis* Riley and *G. salinaris* Bsk. make galls on goldenrod in the United States. The two species last mentioned and probably others are parasitized by tiny, greenish *Hymenoptera* of the species *Copidosoma gelechiæ* How., which we will call the Gelechiid Stem-gall Parasite.

FIG. 148.—Gall of *Gnorimoschema* on goldenrod, split vertically to show larva within.

Gnorimoschema gallæsolidaginis Riley forms oblong galls (Fig. 148) on several common species of goldenrod. The moths emerge from their galls in September or October and lay eggs, a single egg at one place, on stems and the lower dried leaves of goldenrod. The eggs remain on the stem, or on leaves which may fall upon the ground, until the following spring. When the new goldenrod shoots are about 6 inches high, in May, the moths' eggs hatch. The young caterpillar, after hatching, crawls about until it comes in contact with a new goldenrod shoot, or failing to find one soon, it dies of starvation. If successful it crawls up the stem and bores into a terminal bud. Then it eats its way down into the center of the stem and remains there. As the caterpillar continues to eat the interior of the growing stem, a gall forms and within this the moth is

formed, provided the caterpillar is not killed by parasites.

The tiny adults of the Gelechiid Stem-gall Parasite, in September and October, hunt for the eggs of the goldenrod gall-maker *G. gallæsolidaginis* Riley. These eggs are about 1/30 inch long, yellow, and their tough shell is ornamented by polygonal sunken areas all over the surface. The adult parasite in hunting for the eggs runs about over the surface of the goldenrod leaves and stems during the warmer part of the day constantly feeling the surfaces with its antennæ. When the antenna comes in contact with an egg, the parasite climbs upon the egg and begins to drill a hole in it with her sharp ovipositor. (Fig. 149.) The drilling process is slow when compared to the puncturing of a caterpillar by the Militant Noctuid Parasite, for it takes a minute or more for *Copidosoma* to drill the hole and lay a single egg. After laying the egg, she moves on to seek other host-eggs.

Fig. 149.—Female *Copidosoma* ovipositing in egg of *Gnorimoschema*. (Redrawn after Leiby.)

The egg which she inserted into the host-egg is but 1/500 inch long and does not interfere with the development of the host. Both parasite and host continue their embryonic development until cold weather stops them. By that time the host-larva is formed within the egg and inside the larva is the parasite egg. The next spring, when warm weather renews insect activity, our host-larva bursts from its egg shell and enters the goldenrod stem, carrying, embedded in its fat tissue, the partly developed parasite egg.

The parasite egg, although so very small when laid, absorbs nourishment from its host and grows larger. After this increase in food is supplied, the parasite egg behaves in a very remarkable way. Instead of a single embryo forming from the egg nucleus, it becomes divided so as to form a mass of embryos. As the host-larva grows the mass of embryos becomes a mass of parasite larvæ which are set free from the fat tissue into the body cavity of the host. There may be 200 or more complete parasite-larvæ formed from a single parasite egg, and usually there are many more embryos started which are not completed. These incomplete embryos and the weaklings among the completed larvæ are soon devoured by their stronger brothers or sisters. The whole mass is always of one sex. If the parasite egg has been fertilized the resulting larvæ may be either all males or all females. If the egg was not fertilized the larvæ will all be males.

The production of many individuals from a single egg is called *Polyembryony*. This phenomenon is known to occur regularly in several groups of parasitic insects and in the case of one species, *Litomastix truncatellus* Dalm, an average of 1,800 individuals develop from each egg. Other species may produce only twins, or six to eight individuals from an egg.

After the mass of Gelechiid Stem-gall Parasite larvæ is set free in the host's body cavity, the larvæ feed upon the blood, muscles, fat and in fact all parts of the host's body except the chitinous skin, tracheæ and alimentary canal. The result is the death of the host-larva at about the time it would normally have pupated. The parasite larvæ, by this time, have become full grown and they arrange themselves in parallel rows, within the mummified shell of their host. The molted skin of each larva

hardens and forms a wall about it. This is the pupal chamber and within it pupation takes place. Just before pupation, the intestine of the larva becomes opened for the first time and waste is voided into a pupal chamber. The fully developed parasite larva is about 1/16 inch long, with dark jaws and white body. At no time did it possess a caudal vesicle or silk glands such as the Militant Noctuid Parasite has.

After a pupal period of about a month the adults shed the pupal skins within their chambers and gnaw their way out. This is quite a task since the wall of the pupal chamber, the body wall of the host and the stem of the goldenrod must all be pierced before freedom is gained. Having at last gained the outside, the tiny insects fly about and mate with members of their species which have come from other galls. Sometimes the females lay their eggs without having mated but these parthenogenetic eggs will produce only males.

The adults of the Gelechiid Stem-gall Parasite are about 1/16 inch long, with metallic green colored bodies. Females are slightly larger and have yellow legs while males are a trifle smaller and have black legs. Their wings are very clear with almost no veins. The adults live for two or three weeks and feed upon drops of honey dew or nectar.

The parasite, like its host, has but one generation each year. The time of appearance of the pupal and adult stages of the parasite is a few days later than similar stages of the host.

Eight other species of hymenopterous parasites have been bred from the same goldenrod gall-maker. These form a very complex situation and many of them die from the competition of others. Leiby cites two in-

stances where the Gelechiid Stem-gall Parasite and another parasite both matured in the same caterpillar, but the number of individuals in the brood was reduced by the competition.

REFERENCE:

LEIBY, R. W. *Jour. Morphol.*, Vol. 37, p. 195, 1922.

DIGGER WASPS

Example: An "Ammophila" (*Sphex urnaria* Klug.). Family, *Sphecidæ*.

The extreme of narrow-waistedness is found in the family *Sphecidæ*, especially in such members of the family as the common mud-dauber, *Sceliphron cementarium* Dru., and the Ammophilæ (species of the genus Sphex). These insects are called thread-waisted wasps, and the waist has truly the form of a thread. (Fig. 150.) We will apply to *Sphex urnaria* Klug. the common name "Ammophila" because entomologists have commonly known it by this name for many years, although they were under the misbelief that Ammophila was the scientific name of the genus.

Ammophila is a very slender, long-legged, black wasp about an inch long, with an orange band around the abdomen just beyond the waist. The wings are much shorter than the abdomen and are not clear but smoky. These wasps are found in our gardens from June until October. They emerge from their cocoons in the soil in June, and spend some weeks in feeding upon sweetened liquids, such as the nectar of flowers, honey dew or ripe fruits whose skin is broken, using the short, rough-surfaced underlip as a lapping organ, much as a cat uses its

tongue. During this period they mate and, in July, the females begin to make their egg nests. They continue this occupation and their feeding throughout the remainder of the summer. The males are irresponsible creatures which take no part in constructing nests and providing them with food. Probably the individuals of both sexes which do not die from violent or accidental cause before the end of the season are killed by freezing

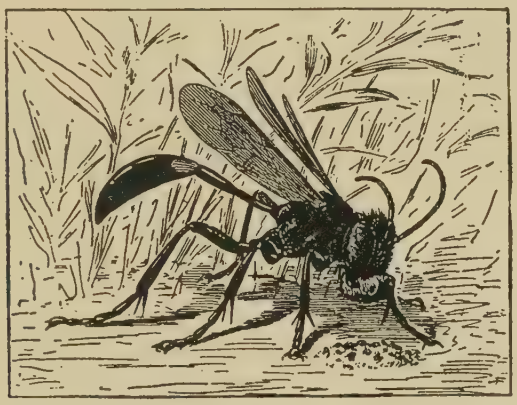


Fig. 150.—Ammophila using stone to pack earth over nest. (From Peckham.)

weather, and the species generally passes the winter as pupæ.

During July, August and September, the female Ammophila is busily engaged in the construction of nests for her young. Each egg must be deposited with two caterpillars of the proper kind which are the food of an Ammophila larva. Moreover, the egg and caterpillars must be placed in a cell two or three inches under the surface of compact soil. Consequently there is much work for the wasp in connection with each oviposition

and it sometimes takes several days to complete the attention given to one egg.

The habits of this wasp in completing its egg nests are among the most interesting phases of insect life. These habits have been carefully studied by the Peckhams in Wisconsin and we will depend very largely upon their accounts.

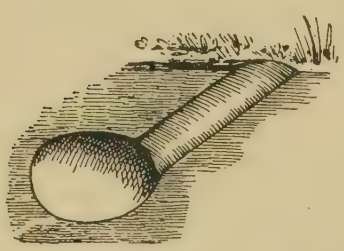


FIG. 151.—Diagram of nest. (From Peckham.)

The female Ammophila is a lover of bright, warm sunshine and in Wisconsin is only actively laboring between approximately 11 A. M. and 3 P. M. on bright summer days. She is a nervous, agile creature, running, leaping, with wings aquiver, and frequently taking short flights. When she begins to feel the pressure of developing eggs within her abdomen, instinct bids her dig a nest. For this purpose she chooses a spot in firm soil such as the edge of a trodden path. It may be in open ground or under the leaves of some plant.

With her mandibles and front legs, she digs a shaft about an inch long and somewhat smaller than a lead-pencil in diameter, directed either obliquely into the soil or straight downward. At the lower end of the shaft she hollows out a cell about ¾ inch in diameter. (Fig. 151.) When the digging has proceeded so far that the wasp is partly hidden, she begins to carry the earth to a little distance from the hole. In doing this she backs out of the hole and flying a little way, gives a sort of twist to the head, which throws the pellet of earth, that she carries in her mandibles, to a distance. Then she alights for a moment and runs or flies back to refill the space

between her mandibles with soil, the process being much like the operation of a steam shovel. The digging of a nest frequently requires an entire day of labor.

Ammophila having made her hole, goes in search of a good sized lump of earth or a stone to fit over the entrance and conceal it from view. Sometimes it requires an hour or more of searching to find a cover which will exactly fit the entrance. She may bring several which are approximately the right size and reject them because they do not fit well enough to suit her. Each one she carries in her mandibles and lowers into the entrance to try its size, then lifts it out and discards it until the proper cover is found.

Having completed the making of a nest and having closed it, her next job is to search for two caterpillars with which to provision the nest. She prefers hairless, green caterpillars of the cut-worm type and will sometimes spend days searching for them among the garden plants. Upon finding a suitable caterpillar, the wasp at once attempts to alight upon it and sting it. Instinctively alert to its danger, the caterpillar repels the attack by rapidly rolling and unrolling its body, with violent contortions, and flinging itself here and there over the ground. The wasp persists in her attempts until she succeeds in straddling her victim near the front end and in grasping its neck firmly with her mandibles. Standing high on her long legs and disregarding the continual struggles of her victim she lifts its front end from the ground, curves the end of her abdomen under its body and jabs the stinger into its lower side between two segments. Instantly there is complete quiet on the part of the caterpillar. The poison from the sting has been injected in the region of the central nerve cord and acts

much like the hypodermic injection of an anæsthetic, given by a surgeon to a human patient.

Limp and helpless, the caterpillar offers no further resistance. For some moments the wasp remains motionless, with her sting inserted into the first point of contact with the victim. Then, withdrawing it, she deliberately plunges the sting into five or six other intersegmental, thin-skinned areas, always choosing the lower surface near the nerve ganglia. She usually injects enough of the

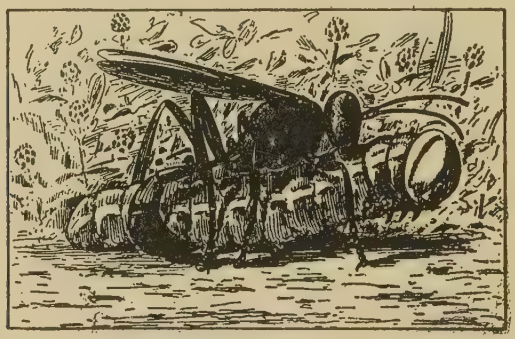


FIG. 152.—Ammophila stinging caterpillar. (From Peckham.)

anæsthetic to keep the caterpillar's body paralyzed for a week or more before she is satisfied to relax and rest.

Having secured her victim, she may take a short rest and clean up a bit if the day is not too far spent. Standing on the ground close by the prize, she begins to rub her body with her long hind legs, standing the while almost on her head with abdomen directed upward. Then she gives her head a thorough washing and rubbing with the front legs, before returning to the caterpillar.

The next process is to grasp the neck of the caterpillar between her jaws and squeeze it repeatedly without

breaking the skin, turning it over and over, so that all sides of the neck are subjected to this kneading process, known as *malaxation*. The result is probably a disorganization of the nerve ganglia in the head and a complete paralysis of the mouthparts. Now the caterpillar is ready to be stored away in the underground nest which was prepared. The nest may be hundreds of feet from where the caterpillar was found, and it is too heavy a load to carry while flying. The little wasp, without hesitation, grasps her burden by the skin of the neck, with her mandibles, and trailing its body between her legs, she drags it over the ground. Usually she will turn it upon its back, so that its feet do not offer resistance to the uneven ground while being drawn over the surface. After many rests and reconnoitering expeditions, the Ammophila brings her caterpillar to the mouth of the burrow and lays it down beside the entrance. Having removed the cover, she again grasps her victim and backing down into the burrow she drags it out of sight.

Having deposited the first caterpillar in the burrow, she again covers the entrance with the pebble or chunk of earth and goes to find another caterpillar. After securing the second victim and depositing it in the burrow, she deposits a single white egg attached to the side of the second caterpillar, then she closes the entrance for the last time and takes no further interest in the nest.

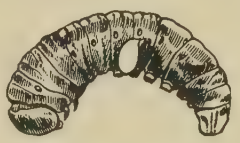


Fig. 153.—Caterpillar with egg of Ammophila attached. (From Peckham.)

The habits of some individuals among the Ammophilæ in closing the nests for the last time are very unique performances. Some members of this species as well as members of closely related species have been observed

by various observers. An account of this performance as carried on by an individual of *Sphex urnaria* is given by the Peckhams' as follows:

"In filling up her nest she put her head down into it and bit away the loose earth from the sides, letting it fall to the bottom of the burrow, and then, after a quantity had accumulated, jammed it down with her head. Earth was then brought from the outside and pressed in, and then more was bitten from the sides. When, at last, the filling was level with the ground, she brought a quantity of fine grains of dirt to the spot and picking up a small pebble in her mandibles, used it as a hammer in pounding them down with rapid strokes, thus making this spot as hard and firm as the surrounding surface. (Fig. 150.) Before we could recover from our astonishment at this performance she had dropped the stone and was bringing more earth. We then threw ourselves down on the ground that not a motion might be lost, and in a moment we saw her pick up the pebble and again pound the earth into place with it, hammering now here and now there until all was level. Once more the whole process was repeated, and then the little creature, all unconscious of the commotion that she had aroused in our minds, unconscious, indeed, of our very existence and intent only on doing her work and doing it well, gave one final, comprehensive glance around and flew away."

Many individuals among the Ammophilæ have not yet reached the "Stone Age" and employ no tool whatever, in addition to the mandibles, for removing the signs of recent excavation from above the nest. Enough individuals have been seen, however, using pieces of wood, stones, and even the leg of a dead grasshopper for a

hammer, to assure us that tool using is not rare among these insects.

Two or three days after the nest was completed, the egg hatches and a white, maggot-like larva, with a pair of tiny, jaws, begins to gnaw into the caterpillar at the point where the egg was attached. The larva devours the interior of the caterpillar within about a week and then bites into the second victim, which is also consumed. Having completed its growth by this time, the larva spins a pale yellowish, silken cocoon. The pupal period within the cocoon varies considerably. In nests made early in the summer, when the weather is warm, the pupal period is short and the wasps emerge in a few weeks. In nests constructed late in the season the pupa may not transform until the following spring, and it is from these late nests that the next year's supply of Ammophila come.

References:

Peckham, Geo. W., and Elizabeth G. Wis. Geol. and Nat. Hist. Surv., Bul. 2, 1898.

Fabre, J. H. *The Hunting Wasps,* Dodd, Mead & Co., 1917.

Rau, Phil and Nellie. *Wasp Studies Afield,* Princeton Univ. Press, 1918.

Social Insects

Example: **The Corn-field Ant** (*Lasius niger americanus* Emery). Family, *Formicidæ.*

The little brown ant, so frequently found in cornfields, is our most common North American ant and probably the most abundant species of insect living in many parts of the continent. The ants and the little piles of soil, marking the entrances to their nests, may be seen on field, pasture, forest, garden, roadway, path, lawn, pave-

ment; from timber line on the mountains to the sandy beach of the ocean. Its home and habits have been studied chiefly in cornfields and, consequently, the common name for the species used by many entomologists is "Corn-field Ant." Its habits are very imperfectly known, yet we can perhaps gain a good general idea of its life from the existing accounts of Forbes and Tanquary.

If one carefully removes the soil about the entrance to a nest and follows the course of the burrows through the soil, he will find a very irregular system of intercommunicating cavities which the ants have excavated. Some of the cavities are an inch or more in diameter, and may be called the chambers, while the cavities connecting them are merely narrow tunnels. (Fig. 154.) No two nests are alike in shape and their size depends upon the size and age of the colony living within. There may be a great many chambers and tunnels, inhabited by an old colony, composed of thousands of individuals, or there may be a single chamber, inhabited by a young female just starting a colony.

The inhabitants of a nest may form a mixed and varied population, consisting of the eggs, larvæ, pupæ, workers, males and females of the ants, together with aphids, mites and other kinds of guests or servants. Ant eggs are very small, oval, white objects, about $\frac{1}{50}$ inch long. The larvæ are white, maggot-like creatures, curved at the smaller end, where a small but distinct head and a pair of jaws are located. The body bears a thin covering of hairs for protection. Like other hymenopterous larvæ living enclosed in chambers, the ant larvæ have no passage from the stomach into the intestine and consequently pass no fecal matter until the end of the larval stage. The pupæ are enclosed in whitish, silken cocoons

FIG. 154.—Interior of portion of an ant's nest. (From Wheeler, after André.)

about ⅛ inch long and it is these, which are called "ant eggs" by the average layman who uncovers a nest and watches the workers carrying away white objects.

The adults of a colony consist mainly of the wingless, brown ants, known as "workers." They have larger heads and slightly thicker front tibiæ than other adults of the species. (Fig. 155.) If the nest is opened in July or August, one may find, in addition to the workers, many winged ants. These are males and "queens." The queen has a larger, fuller abdomen and a smaller head. (Fig. 155.) The winged ants are present only in summer, before they leave the nests to take their nuptial flights, in August and September.

When that time has arrived and a warm, clear day comes, the ants—workers, males and queens—crawl about excitedly over the surface of the ground near the entrance to their nest, usually between 3 and 6 P. M. Every few minutes a male or female will rise into the air and fly away. Other colonies, all over the field, are doing the same thing at about the same hour. The air becomes filled with flying ants. It is supposed that the two sexes mate while in flight. At least, the queens upon descending to the ground, have thousands of spermatozoa stored in the spermathecæ for use in fertilizing their eggs during many future years. The males die of starvation or are eaten by predators soon after their flight. The queens, upon reaching the ground, break off their own wings near the bases, either by rubbing them against objects, or by pulling them off with the legs and jaws. Having rid themselves of wings, the queens burrow into the ground or enter some cavity beneath the bark of a log or under a stone, where each one forms a small cell. Sometimes a queen will find a small queenless colony

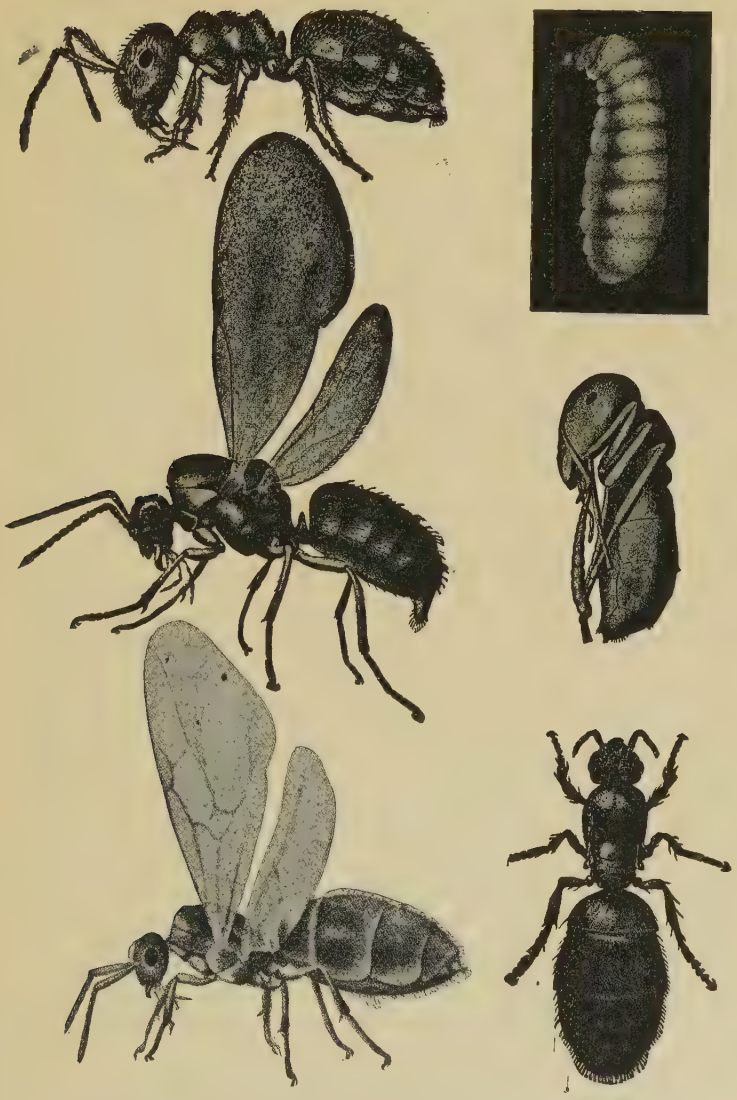


Fig. 155.—Corn-field Ant: worker; larva; winged male; pupa; winged female; female with wings removed. (From Forbes.)

of workers, who adopt her as their own, but usually each queen must start her own colony.

A new colony is started, then, by a fertilized queen forming a cell, a few inches under the ground, and rearing her young there. Some of the queens begin to lay eggs in the fall, but usually they rest in their cells until the next spring before laying eggs. The tiny, white eggs are then produced, a few a time, throughout the growing season. During this first year of the colony about 200 eggs may be laid by the queen, but she does well if she raises 25 of these to the adult stage. The great majority of the eggs and some of the larvæ are eaten either by the queen or by the older members of her brood. This cannibalism is not strange, when one considers the fact that from the time the queen makes her cell in the fall, until she has reared some adult workers the next summer, all the food of the colony comes from her body. Material to form her eggs comes from the fat and wing muscles. The larvæ must be fed upon masticated food regurgitated from her mouth. Since she does not leave the nest to forage, the only available food for her is the supply of eggs she has laid. It is better to eat some than to allow all to die of starvation.

About two months after she begins to rear her young, the queen is rewarded with one or two adult workers, if she has been successful in rearing them. Gradually this number increases until she may have 25 workers by the end of the first season. As soon as workers are mature, they at once take up the duties of foraging for food, feeding the queen and the larvæ regurgitated food, constructing new rooms in which to store the eggs away from the jaws of the larvæ, aiding the larvæ to spin

cocoons and aiding the adults to escape from the cocoons. The queen soon is enabled to give up all duties except egg-laying. No males or queens are formed the first year and in fact none appear before the third year. The great need of the young colony is more workers.

In winter, when the soil becomes cold, the ants, after closing the entrances to their nest, become inactive and remain dormant in the same rooms which they occupied during the summer. No eggs nor pupæ are found during the winter, but larvæ and adults seem to survive equally well. When spring arrives, the workers open up their doors to the outside world and resume activities at the point where cold weather arrested them. The little mounds of earth, appearing around the entrances, are the signs of renewed activity. The development of the younger stages begins when the soil temperature reaches about 70° F.

During the second year, a colony can increase somewhat faster, due to the assistance of more workers. No definite figures are available on the size of a colony at the end of its second year but it seems probable that the average colony might have 100 or more adult workers by that time.

There are no experimental records of the age to which a colony may live, but it is known that it may increase year after year and, under favorable circumstances, give rise to numerous males and queens, who leave the colony to produce new ones, every year after the third. Workers have been known to live six years and Lubbock has kept the queen of another species alive for 15 years in an artificial nest. So, there is reason to believe that colonies of the Corn-field Ant may live for many years.

The extreme hardiness of ants may be judged from the

following tests. They recover from freezing temperatures and temperatures of 100° F. They withstand being submerged in water for 24 hours. They can go without food for several months and they can survive severe injuries to the body. A beheaded worker has been kept alive and active for a month, before it died. Ants are quite resistant to violent poisons, such as corrosive sublimate, potassium cyanide and carbolic acid.

The habits of an ant colony are extremely interesting and many of them may be observed in artificial nests provided with orange colored glass, for ants behave as if in darkness, when ultra-violet light is excluded. The various types of nests in use are described by Wheeler.

The digging of tunnels and chambers is carried on by the workers by means of their mandibles and fore legs. The mandibles, when closed, form a pointed trowel-shaped tool, concave on its lower surface. This tool is used in raking, molding and compressing the earth particles. The mandibles, when open, can grasp and loosen, or carry pellets which are then transported by the mandibles and deposited outside the nest or within the nest if needed there for construction purposes. The ants may carry water in their mouths to moisten soil which is too dry and crumbly for excavation. Excavating becomes necessary when the broods of young require more room for their proper development, when aphids are carried to and from new food plants, and when drouth comes. Drouth will drive the ants down into the soil much deeper than cold. Usually, under normal conditions, they remain but a few inches below the surface, but drouth may cause the colony to burrow down nearly two feet in the soil.

The workers also spend much time acting as nurses for the young. A well fed queen may lay eggs at the rate

of over 100 per day. These are carried from the queen's chamber by nurses and placed in a room containing only eggs. After an incubation period of about 3 weeks the larvæ pierce their egg shells and emerge. The newly hatched larvæ are sorted out and carried into separate chambers, where only larvæ of their age are piled up and fed. To facilitate transportation the larvæ are carried in packets, the individuals in a packet adhering to each other by the hairs on their bodies. The larvæ are fed upon the regurgitated food of the workers and vary considerably in their rate of growth. Some may be fed abundantly and become full grown in about 3 weeks, while others may be fed very little and remain in the larval stage for a year.

When larvæ are ready to spin their cocoons, the workers cover them with soil or particles of débris, so that the larvæ may be surrounded by solid particles to which the first silken threads may be attached. After the cocoon is completed, the workers remove it from the pile and clean off the bits of dirt clinging to it. The cleaned cocoons are then put aside in other piles where pupation is completed in about 3 weeks. When the adult form is completed, workers bite the end off the cocoon, help the pale creature to wriggle out and then strip the old pupal skin off its body, eating the old skin as their reward. For several days after emerging from the pupal case the new ants are fed in the nest by foragers who have returned from outside.

"The nursing instinct of the workers is so overruling that it extends to all the inmates of the nest excepting only strangers of their own species. A common resident of the nest of these ants is a species of mite often found crawling about among the eggs and larvæ, although

never detected in any depredation upon them. It is probably a scavenger of the domicil, and is thus possibly entitled to the protection which it receives. When a nest containing these mites is disturbed, they receive the same attention as its other inmates from the alarmed and anxious workers. In several nests for example, plowed on April 24, in an old oats field, mites were commonly present and the ants seized them in their mandibles and carried them away as they did their own young." (Forbes.)

The ants, however, are very hostile toward members of another colony of their own species, and will attempt to kill any strangers entering their nest. Even members of their own colony, which were kept away from home for 21 days by Forbes, and then allowed to return, were immediately killed upon entering their old home.

"The utility to the ants of this inhospitable savagery —this spirit of ferocious clannishness—is doubtless to be found in their social organization, and in the necessity under which they live of keeping always an active, compact, deeply interested group of workers completely devoted to the care and nurture of their helpless young. No young of any animal can be more utterly dependent than those of these ants, and their feeding and protection must be the constant, consuming care of the whole family group.

"The workers are, on the other hand, among the most active and enterprising wanderers and foragers among insects, traveling far and wide on foot to distances which make it necessary for them to retrace their steps carefully, whether by the aid of the sense of sight or by antennal senses supposed to resemble what in us is the sense of smell. The homing instinct and the nursing in-

stinct are in them so strong as practically to rule their lives. They go abroad in search of food for the family, and to the family they must return, however far they may travel and into whatever difficulties and adventures they may fall by the way.

"These facts make it necessary that there should be in the economy of ant society some self-acting, self-regulating apparatus for keeping the family groups wholly separate and distinct, for making sure that every foraging worker shall find its way back to its own companions—that it shall neither be liable to lose its way completely nor likely to attach itself to an alien family. From this point of view it is greatly to the general interest that it should find a welcome and a permanent home only among its immediate kindred and habitual companions, and nothing could make this condition more secure than a universally hostile reception to the wanderer in every other family group. Clannishness in ants has thus the same justification that it has among savage men. It is a means of maintaining the necessary concentration of the group for the care of the young, and hence for the preservation of the race." (Forbes.)

These ants have no sting but their weapons consist of the sharp, powerful mandibles and poison glands opening at the tip of the abdomen. The poison, which contains formic acid, is sprayed upon wounds made by the mandibles in the bodies of their enemies.

Another interesting relationship found among colonies of the Corn-field Ant is the care of the ants for the Corn-root Aphid (*Aphis maidiradicis,* Forbes). The aphids of this species seem to be very largely dependent upon the ants for their care, and the ants in turn get much of their food from the honey-dew supplied by the

aphids. Like many other species of aphids this species produces a generation of egg-laying females in the autumn. These egg-laying females are captured by the ants and carried in their jaws to the ant's nest. Here, in certain chambers the aphids lay their eggs and the tiny, black eggs are packed away by the ants, with as much care as their own eggs receive. As many as 1,000 aphid eggs have been found in a single nest.

When spring arrives, the young aphids hatch from the eggs in the ants' nest and are transported at once, by underground tunnels, to the roots of early grasses, such as foxtail, and to the roots of smartweed and ragweed. Here the aphids insert their beaks and suck the plant juices so plentifully that a surplus of the sap, modified into honey-dew, passes out through the anus in drops. The ants greedily devour these drops and in fact they often stroke the aphids on the back with an antenna to induce them to yield a drop of the sweet liquid.

In rainy or cold weather, the ants carry their aphids back to the shelter of the nest, and when the aphids become too numerous on a plant to produce much honey-dew, they are moved to the roots of other plants. When corn begins to grow, many of the aphids are transported to the corn roots to feed during the summer, and in some seasons this aphid becomes one of the worst pests of the corn grower. The method of combatting the aphid is to get rid of the ants from the infested field, by deep, fall and spring plowing and harrowing.

"The movements of ants in their outdoor habitations often show a surprising adaptation of habit and behavior to changing conditions in the field. It was repeatedly noticed, for example, that during warm, dry weather in early spring, the aphis eggs would often be brought near

the surface while the larvæ of the ants were kept at a depth of 5 or 6 inches below. The effect of this treatment must be to hasten the hatching of the aphids and at the same time to retard the development of the larvæ of the ants. The growth of the latter is thus kept practically at a standstill while food is scarce in spring, but proceeds at a rapid pace after the aphids have hatched and are yielding an abundant food supply to the colony. In periods of summer drouth the burrows are extended downward to a depth of twelve or fifteen inches, and eggs, larvæ, and pupæ are carried down into relatively moist earth. The ants then mass up in the depths of their burrows and are rarely seen abroad, but communicate with their root-louse herds by means of underground passageways, sometimes several feet in length. When soaking rains come, these hidden colonies open up their burrows to the surface again, as the ground dries off, and resume their more active habits as general foragers.

"Under certain conditions of serious deprivation and suffering, however, this whole system breaks down, and the ants may devour, for their own temporary maintenance, the very objects to which they have previously devoted their entire existence. When infested plants wither and die, and no others can be found to which the aphids may be transferred, these are themselves eaten by the workers as a food material too valuable to waste. When suffering from a lack of sufficient animal food, the workers in our formicaries (ant nests) have occasionally helped themselves to a living pupa of their own species, or have even devoured the larvæ in their charge, to the last one. The corn-field ant is, in fact, essentially a carnivorous insect, and forages actively for animal food, especially when it is without a sufficient number of root-lice.

Much of our breeding-cage work came to naught through the mysterious death of the workers, apparently because their liking for a watery syrup was regarded as evidence that this was a sufficient food for them. In the field and in the insectary we have seen ants feed at various times and under various conditions upon cutworms, carabid larvæ, white grubs, dead May-beetles, dead beetles of the corn root-worm, dead grasshoppers, root-lice, myriapods, earthworms, their own pupæ and larvæ, and the pupal envelopes vacated by adults on transformation. Occasionally they have been seen injuring corn by hollowing out the soft seed either before or after sprouting, and in one case at least they were reported by an insectary assistant as feeding on the fibrous roots of the plant." (Forbes.)

The ants are very careful of the cleanliness of their nest. All refuse material, such as old cocoons, refuse food, dead members of the colony and pellets of excreta, are carried to waste heaps in rooms established for this purpose, or outside the nest. The ants also spend much time cleaning the surfaces of their bodies with their tongues and front legs. The short tongue is rough and is used much like a cat's tongue. A comb-like arrangement of spines at the end of the front tibia makes an excellent structure for cleaning the antennæ and legs. Ants not only lick their own bodies clean but perform this service also for their fellow workers and for the larvæ and eggs.

While queens are usually the only egg-layers and the members of the colony are usually all the offspring of their queen, the workers are also females. Due to insufficient food the workers have, as a rule, but rudimentary ovaries and lay no eggs. Under certain conditions, however, such as the loss of the queen from a colony, it is

known that workers may lay eggs. These eggs are not fertilized and produce in most cases, if not always, males. Therefore a queenless colony cannot long survive the loss of the queen.

References:

Forbes, S. A. Univ. Ill. Agr. Exp. Sta., Bul. 131, 1908.

Tanquary, M. C. Bull. Ill. St. Lab. Nat. Hist., Vol. IX, p. 417, 1913.

Wheeler, W. M. *Ants,* Columbia Univ. Press, 1910.

CHAPTER XXVI

ORDER ISOPTERA

(Gr. isos, equal; pteron, wing)

The members of this order live in colonies like ants and are of several castes, of which only the kings and queens have wings; these are shed after a swarming flight. The two pairs of wings are long, narrow, alike in form, and rest overlapping on the back. The body is soft and usually whitish in color. Mouthparts are for chewing and young resemble the adults.

Isoptera are called termites or "white-ants." Their bodies are of a much more primitive structure than are those of *Hymenoptera,* but the highly developed social organization of the termites can be more clearly understood after consideration of an ant colony, and therefore the brief description of this order is placed last.

Termites are chiefly tropical and sub-tropical insects, although a few species build small colonies in temperate regions such as the Northern United States. They live in colonies like ants, but are pale in color and have the abdomen broadly joined to the thorax. By these characters they can be easily distinguished from ants. Termites differ from ants also in being soft and unable to withstand exposure to dry air; for that reason they build tubes or tunnels constructed of earth and excrement, in which to travel when outside of their galleries.

In the tropics some species build up enormous colonies containing millions of individuals, and their mounds, 15 or 20 feet high, resemble a village of huts constructed by

FIG. 156.—Giant nests of termites in tropical Africa. (From Kellogg.)

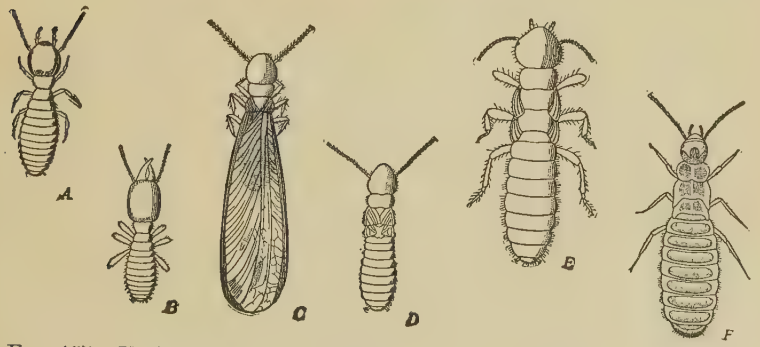


FIG. 157.—Various castes of a termite species. (From Folsom, after Grassi.)

primitive men. The food of termites is mainly dead wood, and frame houses, as well as furniture, are often injured by them. It has been discovered recently that termites can live on a diet of pure cellulose due to the digestive action produced by symbiotic protozoans which normally inhabit the digestive canal.

In the United States the injury of termites to buildings and timbers is confined largely to surfaces which are in contact with moist earth. A building having its wooden surfaces separated from the earth by cement or stone, or the timbers treated with creosote, is immune.

The termites have highly developed societies in which the division of labor is probably greater than that of the ants. There are more castes and each caste includes both male and female individuals. The organization of a colony is too complicated to be adequately discussed here. The reader is referred to the following book, by Wheeler, in which the social life of various groups of insects is summarized in a most interesting manner.

References:

Wheeler, W. M. *Social Life Among the Insects,* Harcourt, Brace and Company, 1923.

Banks, N., and Snyder, T. E. U. S. Nat. Mus. Bul. 108, 1920.

CHAPTER XXVII

THE FAMILIES OF INSECTS

The preceding chapters have discussed the habits of but a few of the multitude of insect species. No one book can contain accounts of all the species and no one person can reasonably hope to learn the habits of all in a life-time. Even the person who takes up entomology as a profession specializes in some limited area of the field, such as the study of insects which are pests of live-stock, or insects of the order *Diptera*. The specialist on live-stock pests sends his flies to the specialist in *Diptera* to be identified.

Let us next consider the groups into which insects have been divided by specialists in entomology. A species is, next to an individual, our most fundamental unit of living animals and plants. Just what a species consists of is often difficult to tell. Where there are many similar individuals possessing varying shades of difference in structure and color, such as we often find among the millions of insects, it is exceedingly difficult to judge where to draw the lines separating them into species. There are other groups of insects which have such distinct characters that the species are easily separated. Careful students of the relationships of insects have reached the conclusion that since any species must have come into being by a gradual process of acquiring characteristics which set it off from its relatives and stopped interbreeding with them, therefore, the poorly defined species of

today are still in the intermediate stages of that process. During the formative period of any species, its characters are poorly defined; individuals at first interbreed freely with any other members of the group, but as the strains begin to separate they interbreed more and more rarely, and with imperfect fertility; the various strains are acquiring adaptations to new environments or conditions which reduce the probability of intermating; and with the decline of intermating variations become more lasting. Finally, distinct species are formed and such species may be defined: *A species is a group of individuals separated from all others by tangible characters and breeding freely among themselves, but not with other individuals.*

In order to make clearer the relationships of species to each other, they have been placed into a series of successively larger groups: *genus, family, order, class* and *phylum*. Besides these, in groups of animals so large and complexly related as the Class Insecta, some intermediate groupings are often used: *subgenus* for a group of species within a genus; *subfamily* for a group of genera (plural of genus) within a family; *suborder* and *subclass* similarly; *superfamily* for a group of families within an order. Groups which are too indistinct to be called separate species are called *races* (sometimes called *subspecies* or *varieties*).

The scientific name of an animal consists of: first, the name of its genus, and second, the name of its species. These names are always in Latin or latinized in form, and are alike to the people of all tongues. All names of genera are written with a capital and all names of species with a small letter. To this combination the name, or an abbreviation of the name, of the author who first described the species is often added. For example the scien-

tific name of the house fly is *Musca domestica* Linn.; *Musca* being the name of the genus, *domestica* the name of the species, and Linnaeus the man who first described the species. When the name of a race is used it is added after the species name, as in the case of *Lasius niger americanus* Emery.

The species and even the genera of insects are too numerous to name here and we can only give a list of the families. The 340 families, which are mentioned on the following pages are arranged in their proper orders and will give to the student an opportunity to locate families mentioned by the instructor or encountered in outside reading. The list of families might be compared to a map showing the countries of the world. We cannot show species and genera any more than we could show all villages and counties on such a map, but it serves the purpose of giving a broad view of all the continents and countries.

ORDERS AND FAMILIES OF THE CLASS INSECTA

Order **Thysanura** (bristle-tails)

1. *Campodeidae,* small, white, long tailed, in humus and decaying vegetation.
2. *Japygidae,* tropical.
3. *Machilidae,* small scaly or hairy, short tailed, scavengers in decaying vegetation.
4. *Lepismatidae,* "silver-fish," nocturnal in houses.

Order **Collembola** (spring-tails)

5. *Poduridae,* flat, not leaping, in decaying vegetation or on pools.
6. *Entomobryidae,* cigar shaped, leaping, on pools, under bark, in nests of ants, etc.
7. *Sminthuridae,* short round, leaping, on pools, damp ground, etc.
8. *Neelidae,* same but with short antenna, under bark, in damp soil, etc.

Order **Plecoptera** (stoneflies)

9. *Pteronarcidae,* fly near streams, young under stones in running water, carnivorous and herbivorous.
10. *Perlidae,* fly near streams, young under stones in running water, carnivorous and herbivorous.
11. *Nemouridae,* fly near streams, young under stones in running water, carnivorous and herbivorous.

12. *Capniidae,* fly near streams, young under stones in running water, carnivorous and herbivorous.

Order **Ephemerida** (May-flies)

13. *Ephemeridae,* near fresh water, young in any fresh water, usually herbivorous.

Order **Odonata** (Dragon-flies, damsel-flies)

14. *Aeschnidae,* dragon-flies, young in mud of ponds and streams, carnivorous.
15. *Libellulidae,* dragon-flies, young in mud of ponds and streams, carnivorous.
16. *Agrionidae,* damsel-flies, young in ponds and streams, have 3 tails.
17. *Coenagrionidae,* damsel-flies, young in ponds and streams, have 3 tails.

Order **Embiidina**

18. *Embiidae,* tropical and sub-tropical, resemble psocids.

Order **Orthoptera**

19. *Blattidae,* cockroaches, omnivorous.
20. *Mantidae,* praying mantis, mostly tropical, predaceous.
21. *Phasmidae,* walking-sticks, herbivorous.
22. *Locustidae* (Acrididae), grasshoppers, locusts, herbivorous.
23. *Tettigoniidae* (Locustidae), green grasshoppers and katydids, herbivorous.

24. *Grylloblattidae,* rare, under stones on mountain.
25. *Gryllidae,* crickets, omnivorous.

Order **Isoptera** (white ants, termites)

26. *Termitidae,* (including Protermitidae, Mesotermitidae, Metatermitidae, Rhinotermitidae) social, build large nests in tropics, eat wood, etc.

Order **Dermaptera** (earwigs)

27. *Forficulidae,* pair of forceps at rear, nocturnal, omnivorous, about gardens and houses.

Order **Coleoptera** (beetles)

28. *Cicindelidae,* tiger beetles, eat insects.
29. *Carabidae,* ground beetles, eat insects.
30. *Amphizoidae,* rare, in cold rapid streams.
31. *Omophronidae,* small, round, in wet sand near streams and ponds.
32. *Haliplidae,* in streams and ponds, carnivorous.
33. *Dytiscidae,* same, predaceous diving beetles.
34. *Gyrinidae,* whirligig beetles, in ponds and streams.
35. *Hydrophilidae,* water scavenger beetles, aquatic or scavengers in damp places.
36. *Silphidae,* burying beetles, eat dead animal or vegetable matter.
37. *Clambidae,* under bark or in decaying vegetable matter, very small, round, dull colored beetles.
38. *Scydmaenidae,* very small, brown beetles found in dead leaves, etc.
39. *Orthoperidae,* tiny dark round beetles in decaying vegetation.

40. *Staphylinidae,* rove beetles, slender, short winged, found in decaying matter, or on plants, etc.
41. *Pselaphidae,* small, dull, short winged, in ants' nests, dead leaves, etc.
42. *Ptilidae,* very minute, in dead leaves, rotten wood, etc.
43. *Scaphidiidae,* small, short winged, in mushrooms.
44. *Histeridae,* small, round or flat, short winged, hard and compact, in carcasses, dung, ants' nests.
45. *Lampyridae,* fire-flies, glow-worms, in grass and low herbs, carnivorous.
46. *Lycidae,* flat, broad, flexible wings, on plants, carnivorous.
47. *Cantharidae,* soldier-beetles, long, narrow, thin winged, on flowers, carnivorous.
48. *Melyridae,* bright blue or green with orange markings, on flowers and in rotting wood.
49. *Cleridae,* small, usually bright colored, on grass, flowers, tree trunks, carcasses, dried animal products.
50. *Lymexylidae,* slender, dark, wood boring beetles.
51. *Mordellidae,* small, slender black beetles, in decaying wood, on flowers and shrubs.
52. *Rhipiphoridae,* same, but larvæ are often parasitic on wasps.
53. *Meloidae,* blister beetles, long, slender with narrow neck, wings flexible, eat leaves.
54. *Pyrochroidae,* usually medium sized, black and red beetles with distinct neck, under bark or in rotting wood.
55. *Pythidae,* of various sizes, shapes and colors, found under bark, in twigs, etc.
56. *Anthicidae,* small, dark, resembling ants, in damp ground, in refuse or on plants.

57. *Rhipiceridae,* large tropical beetles with conspicuous comb-like antennae.
58. *Elateridae,* click-beetles, wireworms, herbivorous.
59. *Throscidae,* very small, slender, resembling click beetles.
60. *Buprestidae,* metallic wood borers.
61. *Dryopidae,* small, dark oval beetles, under stones in streams or damp places.
62. *Georyssidae,* small, compact dark beetles coated with mud or sand.
63. *Dascillidae,* small, dull with downy covering, on flowers.
64. *Helodidae,* small, oblong, pale brown, on marsh plants, larvae aquatic.
65. *Dermestidae,* small, oval, hairy, destructive to animal products.
66. *Byrrhidae,* small, oval, "pill beetles," on grass or leaves of plants.
67. *Nosodendridae,* same, but usually found where sap flows from wounded trees.
68. *Ostomidae,* small, dark, in stored grain, in decaying trees, etc., mostly tropical.
69. *Nitidulidae,* dark, hairy, usually small, variable in shape, in flowers, carcasses, decaying matter, etc.
70. *Cucujidae,* small, flat, elongate, brown, under bark, in stored grain, dried fruits, etc.
71. *Erotylidae,* usually conspicuous, black and red or red and blue, on fungi, clover, etc.
72. *Byturidae,* small, dull yellowish, on flowers and fruit of raspberry, etc.
73. *Mycetophagidae,* small, elongate, often brightly marked with orange, on fungi.

74. *Colydiidae,* small, dark, in fungi and dead wood.
75. *Lathridiidae,* very small, oval, in decaying vegetation, etc.
76. *Endomychidae,* varied, sometimes resemble coccinellids, under dead bark, etc., eat fungi.
77. *Phalacridae,* very small, compact, oval, shining, dark, on composite flowers, etc.
78. *Coccinellidae,* ladybird beetles, predaceous on aphids, scales, a few herbivorous.
79. *Cistelidae,* like tenebrionids, in decaying wood, etc.
80. *Tenebrionidae,* size varied, dark, hard, usually scavengers, but some eat grain, plant roots, etc.
81. *Lagriidae,* like tenebrionids, in rotting wood, leaves, etc.
82. *Monommidae,* small, oval, dull, under bark.
83. *Melandryidae,* usually small, narrow, dull, in rotting wood, fungi, etc.
84. *Ptinidae,* small, boring in lumber, seeds, books, drugs, decaying wood.
85. *Bostrychidae,* dark, cylindrical, head retracted, bore in wood.
86. *Lyctidae,* dark, cylindrical, head retracted, bore in wood.
87. *Sphindidae,* minute, obscure, in wood fungi.
88. *Cisidae,* minute, obscure, in wood fungi.
89. *Scarabaeidae,* dung beetles, May beetles, white grubs, etc.
90. *Trogidae,* skin-beetles, eat dried animal remains.
91. *Lucanidae,* stag beetles, white grubs in decaying wood, etc.
92. *Passalidae,* large, flat, dark, in rotting stumps, etc.
93. *Cerambycidae,* long horned borers.

94. *Chrysomelidae,* leaf beetles, flea beetles, tortoise beetles, etc.
95. *Mylabridae,* small, stout, hairy, in seeds of beans, peas, etc.
96. *Brenthidae,* like curculionids but more elongate, males have short beak, females long beak, bore in decaying wood.
97. *Platystomidae,* beak very short, in dead wood, etc.
98. *Curculionidae,* weevils, curculios.
99. *Scolytidae* (Ipidae), bark beetles.

Order **Strepsiptera**

100. *Stylopidae,* minute parasites in Hemiptera and Hymenoptera.

Order **Thysanoptera** (thrips)

101. *Aeolothripidae,* front wings strongly veined, female with saw-like ovipositor.
102. *Thripidae,* front wings very weakly developed, female with saw-like ovipositor.
103. *Phloeothripidae,* front wings very weakly developed, female without saw-like ovipositor.

Order **Corrodentia** (psocids)

104. *Psocidae,* winged, on bark of trees, eat fungi, lichens, etc.
105. *Atropidae,* wingless, book-lice, eat paste, dried insects, refuse, etc.

Order **Mallophaga** (biting lice)

106. *Trichodectidae,* on dog, cattle, etc.
107. *Philopteridae,* on birds.
108. *Gyropidae,* on mammals.
109. *Liotheidae,* on birds, etc.

Order **Anoplura** (sucking lice)

110. *Echinophthiriidae,* on seals, walrus.
111. *Pediculidae,* on monkeys, apes, man.
112. *Haematopinidae,* on hog, cattle, horse, dog, rat, etc.

Order **Hemiptera** (bugs)

113. *Scutelleridae,* mostly sub-tropical and tropical, usually on plants.
114. *Cydnidae,* usually small and black, on plants or hiding on ground, in ants' nests, etc.
115. *Pentatomidae,* stink bugs, predaceous or plant eating.
116. *Coreidae,* squash bug, leaf-footed bugs, etc., plant eating.
117. *Aradidae,* flat bugs, under dead bark of trees.
118. *Neididae,* stilt bugs, on low herbage or undergrowth in woods, plant eating.
119. *Lygaeidae,* usually small, living on plants, on ground, under stones, etc.
120. *Pyrrhocoridae,* mostly sub-tropical and tropical, cotton stainers, plant eating.
121. *Tingitidae,* lace bugs, on plants.
122. *Phymatidae,* ambush bugs, on flowers, prey upon insects.

123. *Reduviidae,* assassin bugs, on plants or concealed under stones, etc., predaceous on insects.
124. *Nabidae,* on vegetation, predaceous on insects.
125. *Cimicidae,* bed bugs, parasites on birds and mammals.
126. *Anthocoridae,* small, inconspicuous, in flowers, under bark, in houses, etc., predaceous.
127. *Miridae,* plant bugs, feed on plants and other insects.
128. *Hydrometridae,* linear, marsh or pond dwellers, predaceous.
129. *Gerridae,* water striders, predaceous.
130. *Hebridae,* semi-aquatic, about ponds, on duckweed, etc.
131. *Mesoveliidae,* semi-aquatic, about ponds, on duckweed, etc.
132. *Veliidae,* water striders, predaceous.
133. *Saldidae,* shore bugs, predaceous.
134. *Notonectidae,* back-swimmers, carnivorous.
135. *Naucoridae,* in ponds, predaceous.
136. *Nepidae,* on submerged plants, carnivorous.
137. *Belostomatidae,* giant water bugs, carnivorous.
138. *Gelastocoridae,* toad-bugs, on shores, predaceous.
139. *Ochteridae,* semi-aquatic, predaceous.
140. *Corixidae,* water boatmen, eat small aquatic plants, etc.

Order **Homoptera**

141. *Cicadidae,* cicadas, on plants.
142. *Cercopidae,* spittle bugs, on plants.
143. *Membracidae,* tree-hoppers, on plants.
144. *Cicadellidae,* leaf-hoppers on plants.
145. *Fulgoridae,* varied, on plants.

146. *Chermidae,* jumping plant lice.
147. *Aphididae,* aphids.
148. *Phylloxeridae,* aphids, *Adelges* (Chermes), *Phylloxera.*
149. *Aleyrodidae,* white flies, tropical and in greenhouses.
150. *Coccidae,* scale insects, mealy bugs.

Order **Neuroptera**

151. *Sialidae,* aquatic, predaceous.
152. *Raphidiidae,* long necked lace-wings, predaceous, under bark or in crevices.
153. *Mantispidae,* resemble mantids, predaceous, in nests of spiders, etc.
154. *Ascalaphidae,* like dragon-flies, predaceous.
155. *Myrmeleonidae,* ant lions, predaceous, in dry ground.
156. *Chrysopidae,* green lace-wings, predaceous.
157. *Polystoechotidae,* large lace-wing.
158. *Sisyridae,* small, brown lace-wings, aquatic, predaceous on sponges, etc.
159. *Hemerobiidae,* small, brown lace-wings, in woods, predaceous.
160. *Coniopterygidae,* very small, covered with white powder, on bark, eat mites, etc.

Order **Trichoptera** (caddis flies)

161. *Hydroptilidae,* tiny, in standing or flowing water.
162. *Rhyacophilidae,* in flowing water, larvae in cases of stones or sand or none.
163. *Philopotamidae,* in swift water, larvae in silken cases.

164. *Polycentropidae,* in swift or standing water, in silken cases.
165. *Hydropsychidae,* in lakes and swift streams, in silken cases.
166. *Molannidae,* on sandy bottom of lakes and streams, cases covered with sand.
167. *Leptoceridae,* in standing water, very common.
168. *Odontoceridae,* in riffles of swift streams.
169. *Calamoceratidae,* in streams, live in hollow twigs.
170. *Sericostomatidae,* varied.
171. *Limnophilidae,* most common in standing water.
172. *Phryganeidae,* large, caterpillar-like larvae, drag cases in slow water.

Order **Lepidoptera** (moths, butterflies)

173. *Micropterygidae,* leaf miners, moss eaters.
174. *Eriocraniidae,* leaf miners.
175. *Hepialidae,* feed on roots or in stems of plants.
176. *Incurvariidae,* leaf miners, case bearers.
177. *Nepticulidae,* leaf miners.
178. *Cossidae,* borers in wood.
179. *Pyromorphidae,* small, smoky black moths, larvae leaf-skeletonizers.
180. *Megalopygidae,* leaf eaters.
181. *Eucleidae* (Limacodidae), larvae footless, on foliage.
182. *Acrolophidae,* large, stout moths, larvae are burrowing web-worms and eat grass roots.
183. *Tineidae,* clothes moths, scavengers, fungus eaters, etc.
184. *Psychidae,* bag-worms, eat foliage.
185. *Tischeriidae,* leaf miners.

186. *Lyonetiidae,* leaf miners or leaf tyers.
187. *Gracilariidae,* leaf miners.
188. *Coleophoridae,* leaf miners and case bearers.
189. *Elachistidae,* leaf miners.
190. *Heliozelidae,* leaf miners and case bearers.
191. *Œcophoridae,* webworms, in decayed wood, etc.
192. *Ethmiidae,* social webworms.
193. *Stenomidae,* in webs on oak leaves, etc.
194. *Gelechiidae,* leaf miners, stem borers, leaf rollers, seed eaters.
195. *Blastobasidae,* scavengers in acorns, predaceous on oak scale insects, etc.
196. *Cosmopterygidae,* leaf miners, twig borers, etc.
197. *Yponomeutidae,* webworms, often social, fruit miners.
198. *Glyphipterygidae,* leaf tyers, etc.
199. *Heliodinidae,* leaf miners, leaf eaters, predaceous on oak scale insects, etc.
200. *Ægeriidae,* clear wings, borers.
201. *Olethreutidae* (Eucosmidae), fruit worms, twig borers, bud moths.
202. *Tortricidae,* leaf tyers, leaf rollers.
203. *Phaloniidae,* leaf tyers, twig borers, etc.
204. *Carposinidae,* fruit worms, etc.
205. *Pyralididae,* leaf folders, web worms, stem borers, meal worms, grass moths, wax moths, a few aquatic.
206. *Pterophoridae,* feather-wings, leaf eaters, etc.
207. *Thyrididae,* moths with clear spots on wings, larvae plant eaters.
208. *Sphingidae,* humming-bird moths, tomato and tobacco worms, etc., eat foliage.
209. *Geometridae,* measuring worms, eat foliage.

210. *Notodontidae,* oddly decorated caterpillars on tree foliage, etc.
211. *Lymantriidae,* tussock caterpillars, gipsy and brown tail moths, etc., eat foliage.
212. *Noctuidae,* cut worms, army worms, etc., herbivorous.
213. *Agaristidae,* bright colored day-flying moths, larvae eat foliage.
214. *Pericopidae,* bright colored moths, larvae eat foliage.
215. *Arctiidae,* bright colored moths attracted to lights, larvae hairy, on low plants, etc.
216. *Euchromiidae* (Syntomidae), eat grasses, herbs, lichens.
217. *Eupterotidae,* hairy caterpillars on trees and shrubs.
218. *Epiplemidae,* foliage eaters.
219. *Thyatiridae,* foliage eaters.
220. *Drepanidae,* foliage eaters.
221. *Lacosomidae,* foliage eaters.
222. *Citheroniidae,* royal-moths, large larvae armed with spines, foliage eaters.
223. *Saturniidae,* giant silkworms, foliage eaters.
224. *Bombycidae,* silkworm, foliage eaters.
225. *Lasiocampidae,* tent caterpillars, lappet caterpillars, foliage eaters.
226. *Megathymidae,* giant skippers, stemborers, etc.
227. *Hesperiidae,* skippers, larvae narrow-necked, leaf eaters.
228. *Papilionidae,* swallow-tail butterflies, larvae eat foliage.
229. *Pieridae,* white and yellow butterflies, cabbage worm, clover worm, etc.
230. *Nymphalidae,* large or medium butterflies, often brown, larvae often spiny, eat foliage.

231. *Lycaenidae,* small butterflies, often blue, larvae slug-like, herbivorous or predaceous on small insects.

Order Mecoptera

232. *Bittacidae,* resemble crane flies, predaceous in shade.
233. *Boreidae,* wingless, winter forms, found on moss.
234. *Panorpidae,* scorpion flies, carnivorous, in damp, shady situations.

Order Diptera (flies)

235. *Ptychopteridae,* phantom crane-fly, larvae in wet soil.
236. *Anisopidae* (Ryphidae), false crane-flies, larvae in wet, decaying organic matter.
237. *Tipulidae,* crane-flies, larvae in marshy soil, etc.
238. *Psychodidae,* moth-flies, tiny hairy wings, larvae in lavatory traps, dirty pools, etc.
239. *Dixidae,* mosquito-like midges, larvae aquatic.
240. *Culicidae,* mosquitoes, larvae aquatic.
241. *Chironomidae,* tiny midges, larvae in decaying organic waste, in water, etc.
242. *Cecidomyiidae* (Itonididae), gall gnats, larvae in plant galls, fungi, etc.
243. *Mycetophilidae,* fungus gnats, in damp woods, larvae in fungi or decaying vegetable matter.
244. *Bibionidae,* Spring flies, medium sized flies, larvae in soil of cornfields, in decaying vegetation, etc.
245. *Scatopsidae,* minute black flies, larvae in excrement, etc.
246. *Simuliidae,* buffalo-gnats, females blood sucking, larvae attached to stones, etc., under flowing water.

247. *Blepharoceridae,* gnat-like, larvae attached to stones in swift shallow water.
248. *Rhagionidae* (Leptidae), medium sized, large-headed flies, larvae predaceous in wood, bark or soil.
249. *Acroceridae,* small-headed flies, spider parasites, etc.
250. *Stratiomyiidae,* larvae in water, wet soil, decaying vegetation, herbivorous and carnivorous.
251. *Xylomyiidae,* elongate flies, larvae in decayed wood, etc., probably predaceous.
252. *Xylophagidae,* elongate flies, larvae in decayed wood, etc., probably predaceous.
253. *Coenomyiidae,* large brownish fly, larvae predaceous in rotting wood or soil.
254. *Tabanidae,* horse flies, usually large, larvae in damp soil, carnivorous.
255. *Mydaidae,* large elongate flies, larvae in decaying wood, predaceous.
256. *Asilidae,* robber flies, larvae in decaying wood, in soil, etc., predaceous.
257. *Scenopinidae,* small, smooth, black flies, larvae elongate, in decaying wood, fungi, etc.
258. *Bombyliidae,* bee-like flies, very hairy, larvae parasitic on other insects.
259. *Empididae,* slender, predaceous flies, larvae in soil among decaying vegetation, predaceous.
260. *Dolichopodidae,* usually slender green flies often with banded wings, predaceous, larvae in humus soil.
261. *Phoridae,* tiny scavenger flies, larvae scavengers, a few in ants' nests.
262. *Lonchopteridae,* small, pointed-wing flies, larvae flat, live in vegetable matter.

263. *Platypezidae,* larvae broad, flat, live in fungi.
264. *Pipunculidae,* big-eyed flies, in shade, larvae parasitic in leaf-hoppers.
265. *Syrphidae,* hover over flowers, like bees, etc., larvae in decaying organic matter or predaceous, etc.
266. *Conopidae,* large head, slender body, larvae parasitic in wasps, bees, etc.
267. *Ortalidae,* wings ornamented, on meadow plants, etc.
268. *Trypetidae,* wings ornamented, larvae tunnel in fruits.
269. *Sapromyzidae,* larvae in decaying vegetation, in damp woods, etc.
270. *Agromyzidae,* small flies, larvae mine in leaves, stems, etc.
271. *Chloropidae* (Oscinidae), small, yellow-marked flies, larvae in grass stems, etc.
272. *Drosophilidae,* small flies on over-ripe fruit, vinegar, etc.
273. *Sepsidae,* small flies on decaying matter.
274. *Piophilidae,* small flies on cheese, meats, etc.
275. *Ephydridae,* small black flies, larvae in stagnant water, decaying vegetation, salt brine, etc.
276. *Phycodromidae,* small, on ocean beaches, lake shores, etc., scavengers.
277. *Heteroneuridae,* small, in damp shade, larvae in decaying wood, etc.
278. *Sciomyzidae,* brown, spotted-winged flies, larvae aquatic.
279. *Helomyzidae,* small, dark flies, in damp shade, larvae in decaying organic matter.
280. *Borboridae,* small, dark flies, about decaying organic matter.

281. *Psilidae,* carrot rust fly, etc.
282. *Diopsidae,* small, eyes stalked, mostly tropical.
283. *Cordyluridae,* commonly with yellow hairs, flies predaceous, larvae in dung, etc.
284. *Anthomyiidae,* like house fly but smaller, larvae in decaying vegetation, root maggots, etc.
285. *Muscidae,* house fly, etc., larvae in manure, decaying organic matter, etc.
286. *Calliphoridae,* blow flies, blue bottle flies, etc.
287. *Sarcophagidae,* flesh flies, larvae in decaying organic matter, or parasitic in insects, etc.
288. *Tachinidae,* larvae parasites in insects.
289. *Dexiidae,* larvae parasites in insects.
290. *Gastrophilidae,* horse bot flies, larvae parasites in intestine.
291. *Œstridae,* bot flies, larvae parasites in mammals.
292. *Hippoboscidae,* wingless adults parasites on birds and mammals, "sheep tick," etc.
293. *Nycteribiidae,* parasites on bats, wingless.
294. *Braulidae,* minute wingless flies found on bees, larvae in bee hives.

Order Siphonaptera (fleas)

295. *Leptopsyllidae,* some rodent fleas, etc.
296. *Ceratophillidae,* fleas on rodents, birds, etc.
297. *Pulicidae,* fleas.
298. *Echidnophagidae,* jigger fleas, sticktight fleas, etc., mainly tropical.

Order Hymenoptera

299. *Xyelidae,* sawflies, foliage eaters.
300. *Pamphiliidae,* web spinning and leaf rolling sawflies.

301. *Siricidae,* horn-tails, larvae bore in trunks of trees.
302. *Xiphydriidae,* wood boring sawflies.
303. *Cephidae,* stem boring sawflies.
304. *Cimbicidae* (Crabronidae), sawflies, foliage eaters.
305. *Tenthredinidae,* sawflies, larvae eat foliage, some are leaf-miners.
306. *Argidae* (Cryptidae), sawflies, mainly tropical, sweet potato sawfly.
307. *Oryssidae,* parasitic on wood borers, resemble horn-tails.
308. *Braconidae,* parasites of insects.
309. *Ichneumonidae,* parasites of caterpillars, etc.
310. *Trigonalidae,* parasites of insects.
311. *Aulacidae,* parasites of sawfly and beetle grubs.
312. *Stephanidae,* parasites of wood-boring larvae.
313. *Gasteruptionidae,* parasites of bees and wasps.
314. *Heloridae,* parasites of lace-wing pupae.
315. *Belytidae,* parasites of fly larvae, etc.
316. *Proctotrupidae* (Serphidae), parasites of dipterous and coleopterous larvae.
317. *Ceraphronidae* (Calliceratidae), parasites of aphids, dipterous larvae, etc.
318. *Scelionidae,* egg parasites of insects and spiders.
319. *Platygasteridae,* parasites of dipterous larvae.
320. *Pelecinidae,* parasite of white grubs.
321. *Cynipidae,* gall-wasps, larvae in galls on plants or parasitic in insects.
322. *Chalcididae,* parasites of insects, joint-worms of grasses, seed chalcids, fig insects.
323. *Evaniidae,* parasites in eggs of insects.
324. *Pompilidae* (Psammocharidae), long-legged digger-wasps, prey upon spiders, etc.
325. *Cleptidae,* parasites in cocoons of sawflies.

326. *Chrysididae,* bright blue-green cuckoo wasps, larvae parasites of wasps and bees.
327. *Sapygidae,* guests or parasites in nests of bees and wasps.
328. *Tiphiidae,* parasites of underground insects.
329. *Mutillidae,* hairy, bright colored, often wingless, parasites of bees and wasps.
330. *Scoliidae,* digger wasps, predaceous on white grubs.
331. *Formicidae,* ants.
332. *Bethylidae* (Psilidae), parasites of insects.
333. *Vespidae,* wasps, hornets and yellow jackets, eumenids, predaceous on caterpillars, flies, etc.
334. *Dryinidae,* parasites of leaf hoppers, etc.
335. *Sphecidae,* thread-waisted digger-wasps, and other solitary wasps, prey upon insects and spiders with which the young are provisioned.
336. *Prosopidae* (Hydaeidae), wasp-like bees.
337. *Andrenidae,* solitary nest-building and parasitic bees.
338. *Megachilidae,* leaf-cutter, mason and parasitic bees.
339. *Bombidae* (Bremidae), bumble-bees.
340. *Apidae,* honey-bees.

References:

Comstock, J. H. *Introduction to Entomology,* 1924.

Lefroy, H. M. *Manual of Entomology,* 1923.

Brues, C. T., and Melander, A. L. *Key to Families of N. A. Insects,* 1915.

Balfour-Browne, F. *Keys to the Orders of Insects,* 1920.

CHAPTER XXVIII

THE PHYLUM ARTHROPODA

(Gr. arthron, a joint; pous, a foot)

The members of this phylum are distinguished from other animals by the possession of a body composed of a series of rings or segments some of which bear jointed legs.

The *Phylum Arthropoda* is usually recognized as the next to the highest phylum of the Animal Kingdom (the highest being the Chordata—vertebrates—of which man is a representative. The vertebrates possess a bony internal skeletal system in addition to the respiratory, digestive, muscular, nervous, circulatory and reproductive systems which lower animals possess. The internal skeletal system furnishes support for a great mass of cells and consequently the largest animals are vertebrates). The arthropods, on the contrary, have no internal skeleton but a firm covering or exoskeleton. It is excreted from the cells of the body walls, then it hardens and furnishes support to the cells of the body; but this stiff outside covering tends to limit the size to which the animal may grow. It soon becomes "hide bound." The arthropods therefore have remained as the medium sized animals of the kingdom. They vary greatly, of course, but the group as a whole may be considered as

containing intermediate sized members of the Animal Kingdom.

Arthropods are the most commonly seen and widely spread animals on earth. It has been estimated that all other animals taken together are less than one-sixth as many. The members of this group are the most abundant animals found in the air, in the water, on the land.

The Phylum Arthropoda (omitting several small classes not often seen) is composed of five large classes of animals. These are the Class Crustacea, Class Diplopoda, Class Chilopoda, Class Insecta and Class Arachnida.

Class Crustacea (L crusta, crust or shell).

The members of this class have two pairs of antennæ and at least five pairs of legs.

The crustaceans include cray-fishes, lobsters, shrimps, crabs, barnacles, sow bugs, water-fleas, and many minute forms found only upon microscopical examination of the water from streams, lakes or seas. They are exceedingly

FIG. 158.—A shrimp, *Palæmonetes.* (From Hegner.)

numerous and play an important part in the water life of the earth, similar to that played by insects on land.

Crustaceans are essentially aquatic animals; a few of them live in damp places on land, but most of them live in

the water. They breathe either through the general surface of the body or by means of gills. Most of them have a hard shell or crust over the surface of the body, which fact has given rise to the name *Crustacea*. Their growth to the final size is permitted by moulting or shedding the outer shell when it becomes too tight.

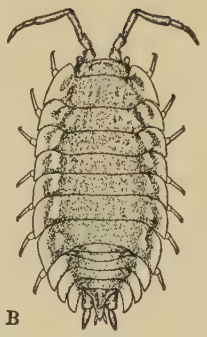


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Fig. 159.—A sow bug, *Oniscus*. (From Hegner.)

Lobsters, shrimps and crabs are used for food by man. The lobster traffic along the Northern Atlantic coast is valued at millions of dollars per year. Crayfish abound in the streams and on wet ground, especially in the lower Mississippi Valley, where they often become so numerous as to render agriculture almost impossible on low ground.

Fig. 160.—A water flea, *Daphne*.

Sow bugs are not aquatic but are found only in damp places such as greenhouses, cellars, gardens, under boards or around wells. They feed at night upon decayed vegetable matter, occasionally attacking the roots and foliage of plants. Mushrooms are sometimes destroyed by them.

Fig. 161.—A common lake and pond crustacean, *Cyclops*.

The smaller forms of *Crustacea* occur in enormous numbers in both fresh and salt water. R. W. Hegner states that the average cubic meter of water in the small Wisconsin lakes contains about 40,000 individuals. They are of importance to us because they form the chief food of many edible fishes.

Class Diplopoda (Gr. diploos, double; pous, foot).

These are arthropods with long, cylindrical bodies and with two pairs of legs on each segment of the body except the first and last. Antennæ short.

The *Diplopoda* are called millipedes or thousand-legged worms. They move very slowly in spite of their many legs. Many of them roll the body into a spiral or ball.

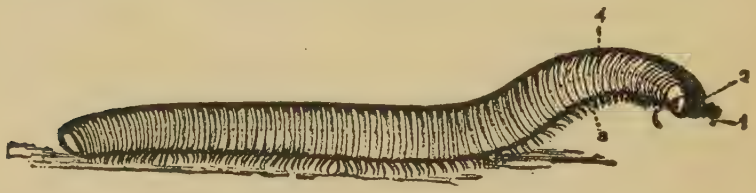


FIG. 162.—A millipede. (From Comstock.)

The millipedes live in dark, moist places and feed mostly on decaying vegetable matter. They sometimes attack sprouting seeds, seedlings and root-crops in gardens and even eat holes in fruits and vegetables which lie upon the ground. Since millipedes are vegetarians they have no poison glands for killing or wounding animals and are therefore harmless to humans.

Class Chilopoda (Gr. cheilos, lip; pous, foot).

Arthropods with long, flattened bodies and with one pair of legs on each segment of the body except the first two and last two. Antennæ long.

The *Chilopoda* are called centipedes or hundred-legged worms. The first segment back of the head bears a pair of leg-like poison fangs by which insects, worms, slugs and other small forms are killed for food. Centipedes are swift-moving creatures. Many of them live under

stones, boards, or the bark of logs. Centipedes of the Northern states are small and not dangerous. There are two species in the Southern states (*Scolopendra heros* and *Scolopendra morsitans*) which attain a length of six inches. A Brazilian species (*Scolopendra gigantea*) is 12 inches long. The bite of these larger species is painful and sometimes dangerous to man.

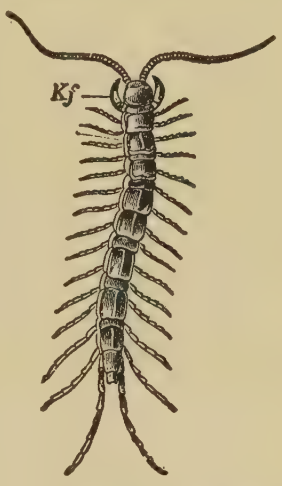


FIG. 163.—A centipede. (From Comstock.)

Class Arachnida (Gr. Arachne, spider).

Arthropods which have four pairs of legs, no antennæ, and which have the head and thorax fused into one solid piece.

The Class *Arachnida* includes the spiders, scorpions, harvestmen, ticks and mites. They are mainly terrestrial and usually feed upon insects or other small animals. In front of the four pairs of legs they have a pair of palpi and a pair of fangs which are used for capturing and crushing their food. There are four principal orders in the *Arachnida,* the orders *Scorpionida, Phalangida, Araneida* and *Acarina.*

Order Scorpionida (Gr. skorpios, scorpion).

The order *Scorpionida* includes the scorpions. They may be distinguished by their large pincer-like palpi and long tail-like abdomens. The scorpions are rapacious feeders upon insects and spiders, capturing the prey with their pincer-like palpi, then stinging it to death by means of the poison-sting located on the end of the tail. The

scorpions live in warm countries. They are common in the Southern states but are not found in the Northern states. They are nocturnal, remaining concealed under stones or in crevices during the day and leaving their hiding places at dusk. When disturbed they are shy and attempt to hide, but if molested, they will sting. The sting will paralyze small animals but does not seriously injure man, except in the case of a few large species which occur in the tropics. Scorpion species vary from one-half inch to eight inches in length when full grown. They grow very slowly. J. H. Fabre found that it took five years for one species to reach maturity. No eggs are laid but the young develop within the mother. After birth the young are carried about upon the mothers until they are able to shift for themselves.

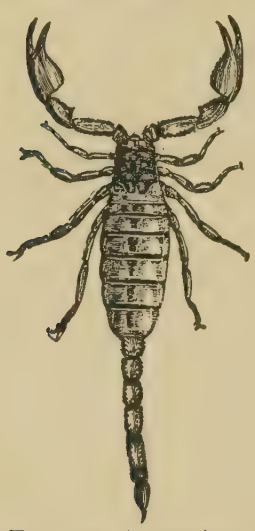


FIG. 164.—A scorpion. (From Comstock.)

Order Phalangida (Gr. phalangion, leg joint).

The order *Phalangida* includes the long-legged arachnids known as harvestmen or daddy-long-legs. They are usually easily distinguished from other animals by their extremely long, slender legs which are bent so that the small oval body appears to be carried near the ground suspended in a swing. Harvestmen are harmless. They feed on dead insects and on soft vegetable matter. Their movement is quite rapid as they climb over other leaves and grass. The harvestmen are common throughout the United States.

Order Araneida (L. aranea, spider).

The spiders differ from other arachnids in having thorax and abdomen joined by a short stalk.

Spiders are among the most commonly seen animals and are almost universally feared because of the belief that their bites are venomous. It is true that spiders bite and inject enough poison to kill an insect into the wounds made by their fangs. But they fear man much more than

FIG. 165.—A harvestman. (From Comstock.)

they are to be feared, and with the exception of a few large species found mainly in tropical or sub-tropical climates their bite does not seriously affect a human being.

Spiders are an important factor in preventing the insects from becoming too numerous and should therefore be regarded as our allies in the struggle for existence. Their food is insects. A spider upon capturing an insect pierces its body with the fangs, injects poison to quiet it, sucks out the juices, then throws the shell away.

The poison of spiders is a clear, oily fluid of acid reaction which stupefies insects immediately. It is secreted in glands within the spider's head and is conducted to the tip of each fang, where it flows out through a small opening when the spider bites.

The webs of spiders are constructed of silk which is produced by glands in the spider's abdomen. The silk

comes out through the spinning organs beneath the rear end of the spider as a liquid but hardens into a thread upon exposure to the air. The spinning organs are small, finger-like projections near the tip of the abdomen. Most spiders possess two or three pairs of spinning organs, each of which may have more than a hundred tiny openings

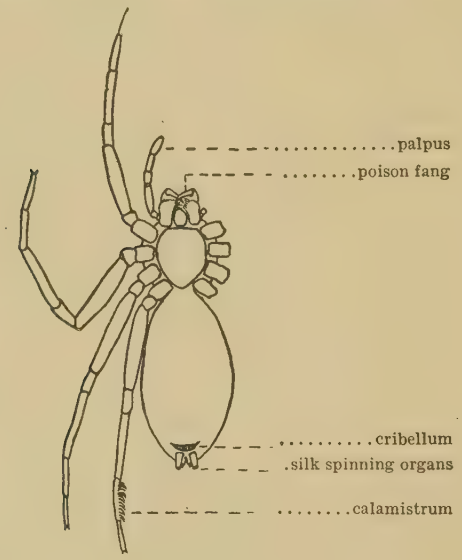


FIG. 166.—Diagram of a spider, ventral view.

at its outer end through which silk is spun. The spinning organs are movable and the spider can separate their tips so as to spin a wide band of silk about an insect and thus secure it quickly or they may be brought together to spin a compact thread.

Those spiders which habitually spin a solid sheet of silk have a comb of spines on the hind leg for sheet spinning. This comb is called a calamistrum. They have also an additional spinning organ just in front of the

others called the cribellum which is covered with hundreds of very fine openings out of which the silk flows. By passing the leg possessing the calamistrum across the cribellum, a sheet of silk can be combed from it. Some spiders can spin a form of silk which remains sticky and insects which come in contact with it must be very strong to escape.

Spiders have four uses for silk.

(1) **Making of egg cases.** The eggs are usually laid in masses and each mass is enclosed in a silken case. These cases may be attached to objects such as plants or stones. In some species the mother carries the egg case about attached to her body until the young are hatched.

(2) **Making tubes or tents** in which to live. Some spiders build no home and live in ready made concealments under stones or in crevices, but many build their homes. Some build silk lined tunnels underground with trap-doors or watch-towers at the entrance. A common form of home used by many families of spiders is that built of silk within a rolled leaf on a plant. Many of the spiders, whose conspicuous webs for capturing prey we see, build near the webs nests from which they watch for their prey and to which they retreat when frightened.

(3) **Making webs or snares** in which to capture prey. The simplest form of web is an irregular maze of threads passing in all directions. A second form consists of a closely woven sheet attached to weeds at its sides. A third form is a sheet of web with a funnel-shaped retreat for the spider at one side. A fourth is triangular in shape. The most complex is the orb-web with its regularly spaced spokes and spirals.

(4) **Locomotion.** Most spiders carry a line of silk with them as they move from place to place, so that

when disturbed they drop quickly away from the disturber and hang suspended by the silken threads until there is no longer danger.

On warm autumn days, when the breeze is gentle, the young spiders of many species go ballooning by means of their silken threads. The spider climbs to the top of a twig, fence post or weed, and spins out a line into the breeze. When the line becomes long enough so that the friction of the air upon it is sufficiently great to lift the spider, he sails away. On clear days you can often see hundreds of the glistening threads far up against the blue sky. The fact that ships have met these threads and spiders hundreds of miles from land shows that the ballooning spiders are carried great distances. This habit tends to give wide distribution to the species. Many a young aviator releases his hold upon the twig before his silken line is sufficiently long or he finds fitful air currents which bring him to earth a few feet from his starting point. The fields may be covered with the silken lines left by such disasters.

FAMILIES OF SPIDERS.

As there are more than forty families in the order Araneida, only a few families of common interest will be mentioned.

Tarantulas (Family *Avicularidæ*). This family contains the giant spiders of the tropics. They build no webs but run rapidly over the ground to catch their prey, which is usually insects. Some of them construct tubes in the ground in which to live and make such closely fitting trap-doors at the entrances that only the owner can discover them without a long search. A few of the largest

species have a body two inches long and they are known to devour young birds.

Funnel-weavers (Family *Agelenidæ*). The funnel-weavers are exceedingly abundant on the grasses, where their webs may be most easily observed while the dew is on. They construct a sheet web with a funnel-shaped retreat at one side. The spider walks on top of her web instead of hanging from the lower surface as most spiders do. She also takes the precaution of leaving the small end of the funnel open so that she may retreat through the back-door in case a dangerous visitor alights on the web.

Cobweb-weavers (Family *Theridiidæ*). The common domestic spiders which spin cobwebs in the corners of our rooms are small, inconspicuous forms. The irregular, unsightly maze of threads spun to snare flies is more commonly seen than the spider which spun them, for it often hides behind the picture molding or other concealment. Other members of the family spin their irregular webs in the fields.

Triangle-weavers (Family *Uloboridæ*). The triangular webs of these small spiders are usually found attached to the twigs of a dead pine or hemlock branch. The spider constructs a regular triangle attached to twigs on two corners and attached to a single thread at the third. The single thread is attached to another twig. The spider rests upon the single thread and pulls it taut, holding some loose line between its legs. When an insect becomes entangled in one of the sticky cross bands of the triangle, the spider suddenly lets go the loose line so that the whole triangle springs forward and entangles the victim in more of the cross bands. This may be repeated several times before the spider goes out to its prey.

Orb-weavers (Family *Argiopidæ*). The regularly spaced lines of an orb-web make it one of the finest works of art constructed by creatures without hands. With infinite pains and remarkable sense of artistic proportion the orb-weaver lays off the radiating spokes, locates the

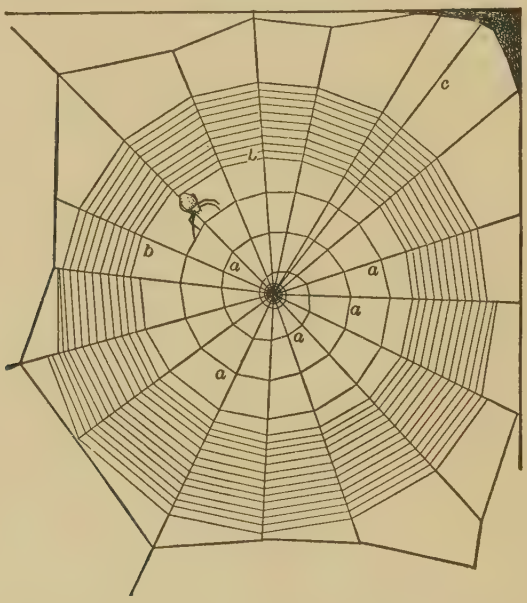


FIG. 167.—Orb web of a spider. (From Hegner.)

hub and covers the spokes with a spirally winding line. The spokes and the area about the hub are made of hard, inelastic silk. The spiral lines are first constructed of hard silk so that the spider may have a safe place to walk while completing the web. Then a second set of spirals is constructed of a sticky elastic silk and the old spirals are cut away. Insects striking the sticky threads become entangled in their efforts to get away. The spider avoids

the sticky threads by walking upon the spokes of the orb as she proceeds to devour the prisoner.

Wolf-spiders (Family *Lycosidæ*). The wolf-spiders chase their prey over the ground. Some species dig tunnels in the earth and build a watch-tower over the entrance to the tunnel. From this watch-tower the spider can more easily sight its prey in the surrounding region by day. By night it leaves the tower to hunt openly.

Jumping-spiders (Family *Attidæ*). These are medium or small sized, bright colored, hairy creatures with short, stout legs and conspicuous eyes. They build no webs, but obtain their prey by quickly jumping upon it. The jumping spiders are quite common on plants, fences or the sides of buildings everywhere. Their queer habits are quite interesting. They seem to stand and stare at you, if you look at them, and moving sidewise or backward is quite as easily managed as moving forward. They can jump quite a distance. Professor J. H. Comstock has seen one attach a line to a vertical wall, jump away from the wall to catch an insect flying near and quickly regain its position on the wall.

REFERENCE:

COMSTOCK, J. H. *The Spider Book*, 1912.

Order Acarina (Gr. akari, mite).

The arachnids of this order usually have no division between thorax and abdomen. The entire body presents an oval, sac-like appearance with no segmentation visible.

The *Acarina* vary in length from one-hundredth inch to one-half inch. The small forms are called mites and the large forms are called ticks. The order is a large

one containing, according to Banks, fully 2,000 species in North America.

The mites are found throughout the world but are most numerous in temperate regions. Because of their small size, mites are not seen by the ordinary observer of nature, yet they are quite common among the fallen leaves, under stones and bark, in loose surface soil, in galls of plants, in streams and ponds, and as parasites on the skins of animals. Many of the species are scavengers and feed upon dead animal or vegetable matter. Others are useful as destroyers of insects and insect eggs. Those mites which we know best, however, are the forms which are injurious or annoying to our bodies or property, such as the chicken mites, scab mites, mange mites, chiggers or "red bugs," cheese mites, and "red spiders."

FIG. 168.—Harvest mites or chiggers. (After Riley.)

Ticks are most numerous in the tropics and very few species occur in northern localities. Of the 400 known species, the great majority are found in Africa. In most localities in the United States, it is possible to find five or six species. Their food is the blood of mammals, of birds and of reptiles. In sucking the blood of their hosts the ticks rarely do great harm, but it has been proven that several species do great injury by carrying diseases from one host to another. The ticks are really a very dangerous group both to man and to the domestic animals and we should make great efforts to exterminate them. The fact that many ticks will suck blood of almost any

kind of mammalian host they can grasp and will later seek another host, offers most favorable opportunities for a disease organism to enter new kinds of hosts where there is no immunity to its ravages. In this way, new diseases may be started. The African relapsing fever and Rocky Mountain spotted fever of man, and the Texas fever of cattle are examples of the diseases transmitted by ticks.

Class Insecta (L. insectum, cut into or segmented).

The members of this class have three pairs of jointed legs and usually the adults possess wings. The head, thorax and abdomen are distinct.

There are about three times as many species of insects as the combined species of all other known animals on the earth. The following table, modified from one by F. E. Lutz, of the American Museum of Natural History, shows the estimated number of described living species of animals:

Insects	475,000
Mollusks	50,000
Fishes	15,000
Birds	13,000
Crustacea	8,000
Worms	7,000
Arachnida	5,000
Protozoa	5,000
Reptiles and amphibians	5,000
Mammals	4,500

Insects have been found living everywhere that man has explored excepting in the depths of the ocean. Some live on ice and snow, others frequent bake ovens; some live in deserts, others live in water; many inhabit living

plants and animals, while others live only in the products of decay; a few live in red pepper, others live in salt vats; some fly high in the air, others burrow in the soil and never see light. It is often stated that if man were not the dominant animal on the earth this would be the Age of Insects. They are the most numerous and widespread animals on the continents of the earth and judging from their apparent success in life it seems that, except for man's ingenuity, they would dominate the earth.

CHAPTER XXIX

SUGGESTIONS FOR COLLECTING INSECTS and KEYS FOR DISTINGUISHING THE PRINCIPAL ORDERS AND FAMILIES OF INSECTS

1. Collecting and Preserving Insects

One of the most fascinating phases of entomological study is the capture of quickly moving insects. In this country, today, few men are able to give vent to their hunting instinct because of the lack of suitable game. It is surprising how excellent a substitute for hunting insect collecting becomes. A man may become fascinated by the chase after an insect but he seldom knows what to do with it after he gets it. Entomologists are constantly receiving boxes containing broken or decayed insects which some one has captured and wants to have identified. Often the remains are so damaged as to be useless and impossible to identify.

In the collection and preservation of insects there are a few essentials which should be known.

The Collecting Outfit

Net. An insect net consists of a cloth bag about 2 feet deep, mounted on a ring of heavy wire or steel, 12 to 14 inches in diameter, and the ring attached rigidly to the end of a wooden handle. The wire ring should be removable from the handle and the ends of the wire

should be separable. The cloth bag has, at the top, a hem through which the wire is inserted, much like a curtain rod is inserted into the top of a window curtain. Nets may be purchased from entomological supply companies or home made.

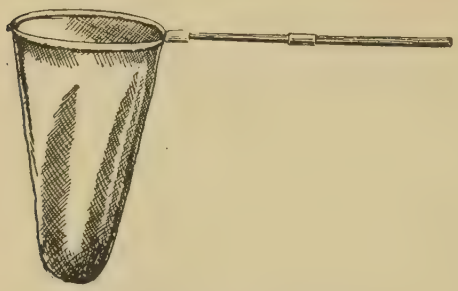


FIG. 169.—Insect net. (From McDunnough.)

Cyanide bottle. For killing the insects captured, the most commonly used implement is a wide-mouthed, hard glass bottle containing in the bottom crystals of potassium cyanide or sodium cyanide, substances extremely poisonous and giving off continually a deadly gas. The layer of cyanide in the bottle is covered with some porous substance, such as cork, blotting paper or plaster of Paris, which will hold the cyanide in place but allow the gas to escape. A few drops of water in dry weather generate

FIG. 170.—Cyanide bottles. (From McDunnough.)

the gas more quickly and increase its efficiency. A bottle with an inch of cyanide in the bottom should last a year before there is need of replacing the cyanide. When cyanide cannot be obtained put a few drops of benzine or ammonia in a tight bottle with the insect to be killed.

Larva bottle. For soft bodied insects, such as caterpillars, grubs, aphids and the young stages of most insects, the cyanide bottle should not be used. Instead, they should be placed as soon as collected into a bottle containing 75 per cent alcohol or 4 per cent formaldehyde solution in water. These solutions kill and preserve the insects but will cause their colors to fade.

Where to Collect

Weeds, high grass, bushes, trees, dead trees, decaying matter, the soil, the air, the water, all yield insects to the observing person. Many insects which are not seen by day may be found on the windows or about lights at night. An electric flashlight will aid in discovering crickets and katydids which sing at night, and cockroaches which run about in dark kitchens, etc. Bird lice may be shaken onto a white paper from freshly killed birds or from birds' nests. Fleas and sucking lice are obtained by combing the hair of mammals.

Preserving Insects

Since the hard part of an insect is its chitinous skin (exoskeleton) the interior may disintegrate without greatly affecting its external appearance. Therefore, the usual way of preserving mature insects, whose surface is firm, is to merely allow the air to dry their bodies. After an insect has dried for a few days the slender appendages become brittle and are broken by the slightest touch.

Therefore, it is necessary, while the insect is still flexible (not more than a day after putting it into the cyanide

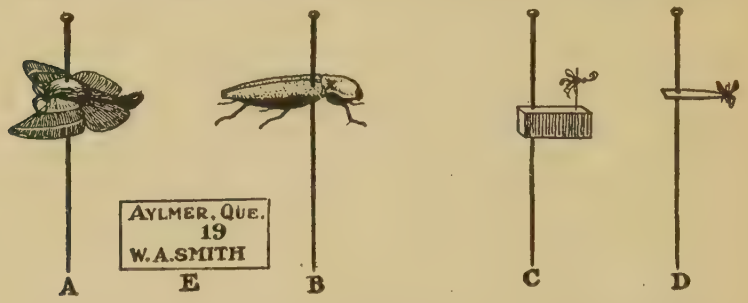


FIG. 171.—Pinned insects: *A*, moth; *B*, beetle; *C*, double pin mount; *D*, cardpoint mount; *E*, locality label. (From McDunnough.)

bottle), to mount it on a pin, as a means of future handling. Long, slender pins, known as insect pins, coated with a black varnish, may be purchased from

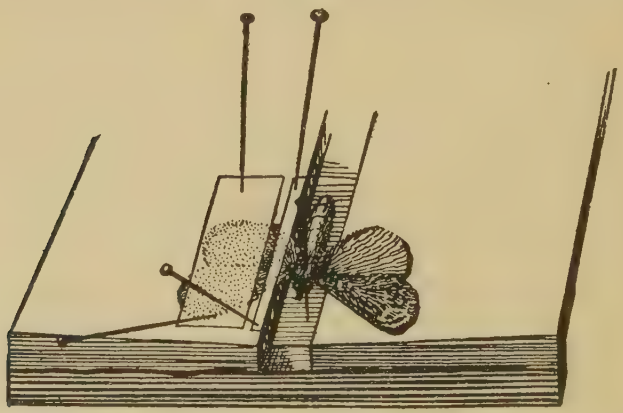


FIG. 172.—Moth spread on spreading board. (From McDunnough.)

entomological supply houses, and such pins are very much superior to ordinary pins, when used for this purpose. If the bare metal comes in contact with the dry-

ing insect, verdigris is liable to form, or the pin may rust.

In pinning most insects, the pin is pushed through the **center of the thorax** from above until about one-quarter of the pin remains above the insect. Beetles are pinned through the **right wing** near the base. Very small insects are mounted in various ways. Most of them may be mounted on the point of a triangle of **cardboard** (Fig. 171) by means of a drop of shellac. Some should be mounted in balsam on glass slides. Moths, butterflies and dragon-flies are usually allowed to dry upon **spreading boards** (Fig. 172), where the wings will dry flat. The wings of most moths and butterflies should be so spread that the rear margin of the front wing forms a right angle with the axis of the body. To draw the wings forward, use a very fine needle or pin back of a strong wing vein, then they may be held in the proper position by tightly pinning strips of tough paper over them. Spread specimens should stand a week to dry before being removed from the spreading board.

After insects have been pinned they may be placed in boxes which have in the bottom a layer of cork, balsa wood or even strips of pith from cornstalks. These substances make it easy to transfer the pins. A tiny rectangular cardboard **label,** bearing the **date** and name of the **locality,** should be on the pin just below the insect. Boxes with tight fitting lids should be used, for mice, cockroaches, and tiny museum pests often eat the dried insects.

In sending pinned insects by **mail,** one must be careful to push all pins very tightly into the cork so they will not jar loose, and the box containing them should be surrounded by several inches of excelsior or cotton. The

exterior of the package can then be wrapped with strong paper and tied securely. (Fig. 173.)

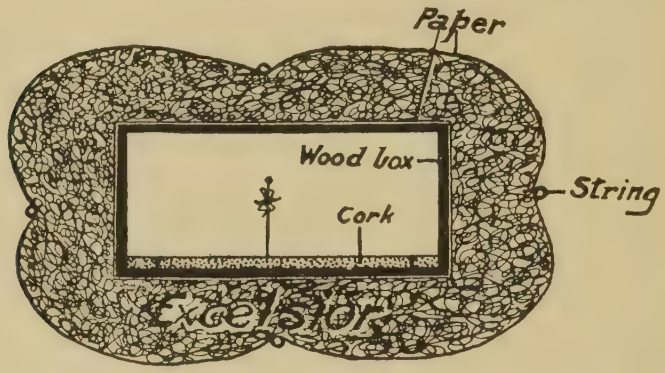


FIG. 173.—Cross section of a package ready for shipment. (From McDunnough.)

The larger moths and butterflies may be placed in envelopes such as those shown in Fig. 174 as soon as they are killed, and stored or shipped in this way, if space

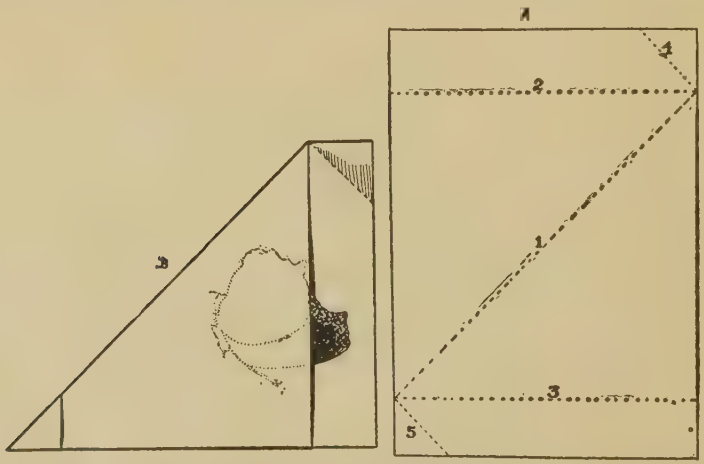


FIG. 174.—Paper envelope for packing Lepidoptera and Odonata. (From McDunnough.)

does not permit their being spread and pinned. The wings of both sides are pushed together over the back by grasping the insect underneath near the base of the wings. In handling them this way you will avoid brushing the scales off the wings.

References:

Banks, Nathan. U. S. Nat. Mus. Bul. 67, 1909.

Lutz, F. E. *Fieldbook of Insects*, 1921.

McDunnough, J. H. Canada Dept. Agr., Ent. Branch, Cir. 12, 1919.

2. Keys to the Principal Orders and Families of Common Insects

A key is nothing more than a short cut to finding out what a specimen is by elimination of other groups. It enables one to avoid looking through all the descriptions and illustrations of hundreds of different kinds. A key contains a series of sets of two opposing statements, one of which statements must be eliminated at each step. After choosing which of the two opposing statements is correct the next step is to consider the set to which the number at the right directs.

It has been the endeavor of the writer to choose the families of insects which are most commonly collected by the average student and to construct simple non-technical keys for his use in the class-room. Undoubtedly there are many exceptions to the statements made on the following pages. In addition to the great number of insects excluded from the keys intentionally there are probably some forms which will not fit in the places meant for them. The keys have been used for several years in the classes of the writer and of his colleagues and have been revised several times.

A. ADULT INSECTS

KEYS FOR DISTINGUISHING THE ORDERS OF INSECTS

WINGED INSECTS

175.—Snout beetle.

1. Upper wings hard, meeting in a straight line along middle of back; under wing usually hidden; mouth with jaws for chewing (sometimes with long beak which has jaws on tip). Fig. 175. (Beetles) page 412. Order *Coleoptera*
1. Not such insects..... 2

176.—Fly.

2. Wings thin, transparent and only two in number; mouth without jaws but formed for sucking or piercing. Fig. 176. (Flies, mosquitoes) page 418. Order *Diptera*
2. Not such insects..... 3
3. All four wings and body densely covered with dust-like scales. (Moths, butterflies) page 415. Order *Lepidoptera*
3. Not such insects..... 4

177.—Wasp.

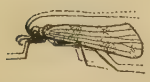
4. Four thin transparent wings each with less than seven long veins; upper wings the larger; jaws for chewing and often also with tongue for lapping. Fig. 177. (Bees, wasps) page 421. Order *Hymenoptera*
4. Not such insects..... 5

178.—Bug.

5. Wings overlapping and resting tightly upon the back; upper wings thickened at base, thinner at tip; mouthparts forming a jointed beak. Fig. 178. (True bugs) page 408. Order *Hemiptera*
5. Not such insects..... 6

179.—Leafhopper.

6. Upper wings of uniform thickness, slanting roof-like from sides of body; mouthparts forming a jointed beak. Fig. 179. (Leafhoppers, cicadas, etc.) page 411. Order *Homoptera*
6. Not such insects..... 7



180.—Caddis fly.

7. Slender moth-like insects with no mouthparts visible except a pair of slender palpi; upper wings are not clear but slightly darkened, spotted or hairy, held flat against sides of body and are broadest beyond the middle. Fig. 180. (Caddis flies.) Order *Trichoptera*
7. Not such insects..... 8

181.—Cricket.

8. Mouth for chewing; wings usually wrapped about body; upper wings of denser material than lower ones which are thin and transparent. Fig. 181. (Grasshoppers, cockroaches, crickets, etc.) page 407. Order *Orthoptera*
8. Not such insects..... 9

182.—Net winged.

9. Wings prominent, usually nearly flat; all four wings thin, transparent and netted with many veins; mouth chewing. Fig. 182. (Net winged insects) page 405.
Several orders of.....*Neuropteroids*
9. Tiny, slender insects with four very narrow transparent wings and the wings having a long fringe of hairs. Fig. 183. (Thrips.) Order *Thysanoptera*

183.—Thrips.

Wingless Insects

1. Ant-like, abdomen joined to thorax by slender stem; mouth chewing. Fig. 184, page 421. Order *Hymenoptera*
1. Not such insect..... 2

184.—Ant.

185.—White ant.

2. Ant-like; nearly as wide across waist as elsewhere; body light colored and cylindrical, not flattened. Fig. 185. (White ants or termites.) Order *Isoptera*
2. Not such insects..... 3

186.—Book louse.

3. Small insects; body flat and broad across back; head as wide or nearly as wide as body; mouth chewing..... 4
3. Not such insects..... 5

4. Antenna of many segments. Fig. 186. (Book lice.) Order *Corrodentia*
4. Antenna short, of not more than 5 segments. Fig. 187. (Bird lice.) Order *Mallophaga*

187.—Bird louse.

5. Small, smooth, soft bodied; head small; abdomen very plump with pair of short tubes on top or rear; slender legs and antennæ. Fig. 188. (Plant lice) page 411. Order *Homoptera*
5. Not such insects..... 6

188.—Plant louse.

6. Small; broad and flat across back; fleshy legs each with single hook-like claw for grasping hairs; fleshy unjointed sucking beak. Fig. 189. (Lice.) Order *Anoplura*
6. Not such insects..... 7

189.—Louse.

7. Small spiny insects; body flattened on sides; hind legs longer for jumping; tarsus (foot) of five segments; beak for sucking. Fig. 190. (Fleas.) Order *Siphonaptera*
7. Not such insects..... 8

190.—Flea.

8. Small delicate insects with long slender tails and antennæ; no visible mouthparts. Fig. 191. (Bristle-tails, "fish moths.") Order *Thysanura*
8. Not such insects..... 9

191.—Bristle-tail.

9. Tiny, delicate insects with abdomen of six segments; arising from beneath fourth abdominal segment is a long usually forked appendage for leaping. (Spring-tails.) Order *Collembola*

9. Not such insect.....10

10. Body densely covered with scales or fine hair; mouthparts absent or for sucking (some female moths of the families Geometridæ and Lymantriidæ). Order *Lepidoptera*

10. Not such insect.....11

11. Mouthparts for chewing.....12

11. Mouthparts for sucking.....13

12. Antenna thread-like; head with face directed ahead or downward (crickets, grasshoppers, cockroaches) page 407. Order *Orthoptera*

12. Antenna bead-like, club-like or comb-like; head with face directed upward (beetles) page 412. Order *Coleoptera*

192.—Coccidae.

13. Small legless insects immovably attached to host plant, or if with legs the body is covered with a white mealy powder and the tarsus has but one segment. Fig. 192. (Scale insects) page 411. Order *Homoptera*

13. Legs well developed; beak easily distinguished arising at front of head and curving back beneath it. (Bugs) page 408. Order *Hemiptera*

KEY TO THE ORDERS OF **NEUROPTEROIDS** (*Neuroptera* and their allies)

193.—May-fly.

1. Upper wings large, held vertical above body; lower wings very small; abdomen with long, fragile tails; antenna inconspicuous. Fig. 193. (May-flies.) Order *Ephemerida*

1. Not such insects..... 2

194.—Mecoptera.

195.—Damsel fly.

196.—Dragon fly.

197.—Myrmelionid.

198.—Dobson fly.

199.—Lacewing.

2. Head prolonged into a trunk-like beak. Fig. 194. (Scorpion flies.)
Order *Mecoptera*
2. Head not prolonged into a beak..... 3

3. Antenna very short and inconspicuous; wings long, narrow and with a joint near middle of front margin; very long, slender insects 4
3. Antenna fairly long and easily seen; wings without a joint on front margin 5

4. Front and hind wings equal in size and shape. Fig. 195. (Damsel flies, Zygoptera.) Order *Odonata*
4. Hind wings broader than front wing near base. Fig. 196. (Dragon flies, Anisoptera.) Order *Odonata*

5. Antenna enlarged at the tip; body and wings very long and slender. Fig. 197. (Ant lions, family Myrmelionidæ.)
Order *Neuroptera*
5. Antenna not enlarged; body not extremely long and slender..... 6

6. Large insects; wings overlapping on back except at the tip where they are separated; jaws usually prominent; wings prominently veined. Fig. 198. (Dobson flies, family Sialidæ.)
Order *Neuroptera*
6. Not such insects..... 7

7. Very delicate, fragile insects with greenish or clear lacy wings which are flat, equal in size and never overlapping on the back. Fig. 199. (Lacewing flies, family Chrysopidæ.)
Order *Neuroptera*
7. Not such insects; wings entirely overlapping on back when at rest..... 8

200.—Stone fly.

8. Wing veins distinct; abdomen often with pair of short tails; thorax in front of wings large and flat. Fig. 200. (Stone flies.) Order *Plecoptera*

201.—White ant.

8. Wings whitish, equal in size and with indistinct veins; thorax in front of wings very short. Fig. 201. (Termites or white ants.) Order *Isoptera*

KEY TO FAMILIES OF THE ORDER **ORTHOPTERA**

202.—Long-horned grasshopper.

1. Third pair of legs much the larger, for leaping 2
1. Third pair of legs not enlarged for leaping 4
2. Antenna much shorter than entire body, tarsus (foot) of 3 segments—(grasshoppers, locusts) (formerly Acrididæ). Family *Locustidæ*
2. Antenna long as body, tarsus of 3 or 4 segments 3

203.—Cricket.

3. Tarsus of 4 segments. Fig. 202. (Long-horned grasshoppers and katydids) (formerly Locustidæ). Family *Tettigoniidæ*
3. Tarsus of 3 segments. Fig. 203. (Crickets.) Family *Gryllidæ*

204.—Cockroach.

4. Body oval, flat, shining brown or yellow-brown. Fig. 204. (Cockroaches.) Family *Blattidæ*
4. Not such insects..... 5

205.—Praying mantis.

5. Body long, slender; front legs much stouter, armed with spines for grasping prey. Fig. 205. (Praying mantis.) Family *Mantidæ*

206.—Walking stick.

5. Body long, very slender; front legs spineless and no stouter than others. Fig. 206. (Walking-sticks.) Family *Phasmidæ*

KEY TO FAMILIES OF THE ORDER **HEMIPTERA**

207.—Pentatomid.

1. Antenna at least as long as head..... 2
1. Antenna short, hidden beneath eyes..14

2. Antenna of five segments..... 3
2. Antenna of three or four segments... 4

3. Shoulder pointed; triangular piece on center of back terminating in a rounded tongue at rear. Fig. 207. (Stink bugs.) .....*Pentatomidæ*
3. Shoulders rounded; no rounded tongue on center of back. Fig. 208. (Negro bugs.) .....*Cydnidæ*

208.—Cydnid.

209.—Water strider.

4. Tarsal claws arising from end of tarsus 5
4. Tarsal claws arising from sides of tarsus above the end. Fig. 209. (Water striders.) .....*Gerridæ*

210.—Lace bug.

5. Upper wings resembling network or lace; small insects. Fig. 210. (Lace bugs.) .....*Tingitidæ*
5. Upper wings not resembling lace or absent 6

211.—Phymatid.

6. Femur of front leg nearly as broad as long; antenna knobbed (often hidden at side of thorax). Fig. 211. (Ambush bugs.) .....*Phymatidæ*
6. Front femur not much thickened; antenna not knobbed nor hidden..... 7

7. Body broadly oval and very flat; usually wingless or with dwarfed wings..... 8
7. Body not greatly flattened..... 9

212.—Flat bug.

8. Tarsus with two segments. Fig. 212. (Flat bugs.) .....*Aradidæ*
8. Tarsus with three segments. Fig. 213. (Bedbugs.) .....*Cimicidæ*

213.—Bedbug.

9. Head long and narrow behind the eyes; beak curved; front femur often thicker than others.....10
9. Head short behind the eyes; beak nearly straight; front femur not thickened..11

214.—Assassin bug.

10. Sides of abdomen higher than middle; wings lying between and not covering the high lateral margins of abdomen; beak short and stout. Fig. 214. (Assassin bugs.) .....*Reduviidæ*
10. Abdomen higher in middle; wingless or wings covering entire abdomen; beak long and slender. Fig. 215. (Damsel bugs.) .....*Nabidæ*

215.—Damsel bug.

11. Thin part of upper wing with more than seven long veins.....12
11. Thin part of upper wing with less than seven long veins.....13

216.—Pyrrochorid.

12. Thin part of wing with one or two looped veins making large rounded cells at base; about eight long veins arising from the looped veins and branching. Fig. 216. (Red bugs.)...*Pyrrochoridæ*
12. Thin part of wing with no looped veins nor large cells at base but with very many long veins. Fig. 217. (Squash bugs, etc.).....*Coreidæ*

217.—Squash bug.

218.—Lygæid.

13. Thin part of wing with four or five long straight veins. Fig. 218. (Chinch bugs, etc.) .....*Lygæidæ*

13. Thin part of wing with no long straight veins but with one or two looping veins at the base. Fig. 219. (Leaf bugs.) (Capsidæ.) .....*Miridæ*

219.—Leaf bug.

220.—Giant water bug.

14. Large flat broadly oval insects of brown color; at least three-fourths inch long. Fig. 220. (Giant water bugs.) *Belostomidæ*

14. Not such insects.....15

221.—Water scorpion.

15. Long, slender insects with tail-like tube on rear. Fig. 221. (Water scorpions.) *Nepidæ*

15. Short insects without tail-like tube..16

222.—Water boatman.

16. Back nearly flat; beak very broad and short. Fig. 222. (Water boatmen.) *Corixidæ*

16. Back high along middle; beak not very broad. Fig. 223. (Back swimmers.) *Notonectidæ*

223.—Back swimmer.

KEY TO FAMILIES OF THE ORDER **HOMOPTERA**

224.—Cicada.

1. Large insects usually over one inch long; clear glassy wings with dark prominent veins. Fig. 224. (Cicadas.) *Cicadidæ*
1. Small insects usually less than one-half inch long 2

2. Wingless; legless; immovably attached to host plant, or if with legs the body is covered with white mealy powder and tarsus has but one segment. Fig. 192. (Scale insects.) ..... *Coccidæ*
2. Not such insects 3

225.—White fly.

3. Antenna long and prominent 4
3. Antenna very short and not easily seen 6

4. Wings opaque, covered with mealy powder. Fig. 225. (White flies.) *Aleyrodidæ*
4. Wings transparent or wingless 5

226.—Psyllid.

5. Wingless or winged; head narrower than abdomen; a pair of tubes (cornicles) arising from top or rear of abdomen. Fig. 188. (Plant lice, aphids.) *Aphididæ*
5. Head broad as abdomen; winged; without cornicles. Fig. 226. (Jumping plant lice.) (*Chermidæ*.) ..... *Psyllidæ*

227.—Membracid.

6. Head end of body much wider than elsewhere; grotesque creatures with thorax covering head and usually with one to three horns. Fig. 227. (Tree hoppers.) ..... *Membracidæ*
6. Head end not widened; thorax not covering head 7

228.—Fulgorid.

7. Antennæ arising from sides of head beneath the eyes. Fig. 228. ..... *Fulgoridæ*
7. Antennæ arising from front of head between the eyes 8

8. Tibia of hind leg armed with one or two stout teeth, and its tip with circle of short spines. (Spittle insects, leafhoppers.) .....*Cercopidæ*
8. Tibia of hind leg armed with a row of spines on lower side. Fig. 179. (Leafhoppers.) .....*Cicadellidæ*

KEY TO FAMILIES OF THE ORDER COLEOPTERA

229.—Snout beetle.

1. Head prolonged into a beak; antenna elbowed and arising distant from eye. Fig. 229. (Snout beetles.) *Curculionidæ*
1. Head not prolonged into a beak..... 2

230.—Engraver beetle.

2. Head deeply sunken in the thorax; small stout cylindrical body truncated before and behind (rarely oval); color uniform black or brown. Fig. 230. (Engraver beetles.) .....*Scolytidæ*
2. Not such beetles..... 3

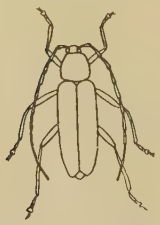
231.—Ladybird beetle.

3. Tarsi of fore and hind legs with same number of segments..... 4
3. Tarsi of fore and middle legs five segmented; hind tarsi four segmented...19

232.—Leaf beetle.

4. Tarsi three-segmented. Fig. 231. (Lady birds.) .....*Coccinellidæ*
4. Tarsi four or five segmented..... 5

5. Tarsi apparently four segmented.... 6
5. Tarsi five segmented..... 7



233.—Long-horned borer.

6. Body oval; antenna shorter than body. Fig. 232. (Leaf beetles.) .*Chrysomelidæ*
6. Body and antenna long. Fig. 233. (Long-horned borers.)....*Cerambycidæ*

7. First three segments of abdomen on lower side not distinctly separated; antenna usually thread-like..... 8
7. Segments of lower side of abdomen distinct; antenna enlarged at tip or saw-like 11

8. Legs adapted for running..... 9
8. Legs adapted for swimming.....10

234.—Tiger beetle.

9. Antennæ inserted on front of head above base of jaws. Fig. 234. (Tiger beetles.) *Cicindellidæ*
9. Antenna inserted on side of head between base of jaw and eye. Fig. 235. (Ground beetles.) .....*Carabidæ*

235.—Ground beetle.

10. With eyes divided by margin of head into upper and lower halves. Fig. 236. (Whirligig beetles.) .....*Gyrinidæ*
10. With eyes not divided into halves. Fig. 237. (Diving beetles.).....*Dytiscidæ*

236.—Whirligig beetle.

11. Antenna with enlarged tip (club shaped) 12
11. Antenna not enlarged at tip but more or less saw-like.....17

237.—Diving beetle.

12. Enlarged tip of antenna composed of flat layers bound together at one side only 13
12. Enlarged tip of antenna a solid rounded club 14

238.—Stag-beetle.

13. Layers of antennal club not pressed together; often large jawed insects. Fig. 238. (Stag beetles.).....*Lucanidæ*

239.—May beetle.

13. Layers of antennal club pressed closely together or their bases united. Fig. 239. (May beetles, tumble bugs.) *Scarabæidæ*

240.—Water scavenger.

14. Legs adapted for swimming. Fig. 240. (Water scavengers.).....*Hydrophylidæ*
14. Legs for walking.....15

241.—Rove beetle.

15. Upper wings very short, exposing more than last three abdominal segments. Fig. 241. (Rove beetles.) *Staphylinidæ*
15. Upper wings exposing not more than three abdominal segments.....16

242.—Dermestid beetle.

16. Small stout hard oval beetles with five segments on lower side of abdomen. Fig. 242. (Skin beetles, larder beetle, museum pests.) .....*Dermestidæ*
16. Larger beetles with wings short, or broad and nearly flat; six or more segments of abdomen. Fig. 243. (Carrion beetles.) .....*Silphidæ*

243.—Carrion beetle.

244.—"Firefly" beetle.

17. Surface somewhat soft and flexible; seven or eight visible abdominal segments below. Fig. 244. (Fireflies.) *Lampyridæ*
17. Surface very hard and firm; five visible abdominal segments below.....18

245.—Click beetle.

18. Thin flexible joint between front part of thorax and after body; rear angles of front part of thorax sharp pointed. Fig. 245. (Click beetles.)....*Elateridæ*

18. No flexible joint in thorax. Fig. 246. (Metallic wood borers.).....*Buprestidæ*

246.—Metallic wood borer.

247.—Blister beetle.

19. Head wider than first part of thorax; claws cleft or toothed. Fig. 247. (Blister beetles.) .....*Meloidæ*

248.—Darkling beetle.

19. Head narrower than thorax; claws simple. Fig. 248. (Darkling beetles.) *Tenebrionidæ*

KEY TO FAMILIES OR SUPERFAMILIES OF THE ORDER LEPIDOPTERA

1. Antenna thread-like with a knob at tip 2
1. Antenna thread-like or feathery; not knobbed (moths) 6

249.—Skipper.

2. Antennal knob not curved back; body slender (butterflies) 3
2. Antennal knob usually curved back at tip; body stout; moth-like. Fig. 249. (Skippers.) .....*Hesperiidæ*

250.—Nymphalid.

251.—Pierid.

252.—Swallow-tail.

253.—Lycænid.

254.—Clear-winged moth.

255.—Sphingid.

256.—Leaf roller moth.

3. Front legs very small and uselessly held against breast; large or medium usually brown butterflies. Fig. 250. (Four-footed butterflies.) .....*Nymphalidæ*
3. Front legs nearly as large as other legs and with claws; tibia not held against breast 4

4. Yellow, orange or white wings often marked with black; regularly rounded wings; common butterflies. Fig. 251. *Pieridæ*
4. Not such butterflies..... 5

5. Large uncommon forms usually black, marked with yellow or blue; hind wing irregular and usually with a tail-like projection. Fig. 252. (Swallow-tails.) *Papilionidæ*
5. Small blue, violet or brown forms; regularly rounded wings. Fig. 253. *Lycænidæ*

6. Wings completely covered with scales (or if clear-winged the antenna is thicker near tip than at base)..... 7
6. Wings all or partly clear and free from scales; slender moths. Fig. 254. (Clear-winged moths.) (*Sesiidæ.*)...*Ægeriidæ*

7. Large sized, slender-winged smooth moths with sharp pointed abdomen (rarely with clear wings and tufted tail); antenna tapering towards both ends. Fig. 255. (Humming bird moths.) .....*Sphingidæ*
7. Not such moths..... 8

8. Small, broad winged moths; front margin of fore wing curved suddenly outward near base so as to form a decided shoulder; front wing usually under one-half inch long. Fig. 256. (Leaf rollers.) *Tortricoidea*
8. Not such moths..... 9

257.—Tineid.

9. Very small moths; narrow wings; fringe on rear of hind wing nearly as long as or longer than width of the wing. Fig. 257. (*Tineina.*) .....*Tineidæ*

9. Large or small moths; fringe on hind wings not approaching width of wing 10

258.—Grass moth.

10. Small slender pale colored moths; long palpi projecting from front of head like a beak; fore wings narrow with square cut ends. Fig. 258. (Grass moths.) (*Crambinæ.*) .....*Pyralididæ*

10. Not such moths.....11

259.—Saturniid.

11. Very large, broad winged thick bodied moths with a prominent eye-like spot on wings. Fig. 259. (Giant silkworms.) *Saturniidæ*

11. Not extra large moths or if large the eye-like spot is lacking.....12

260.—Lasiocampid.

12. Light brown short stout hairy moths with oblique stripes across fore wing; front edge of hind wing curved widely outward at the base; antenna comb-like. Fig. 260. (Tent caterpillars.) *Lasiocampidæ*

12. Not such moths.....13

261.—Pyralid.

13. Hind wing with three complete unbranched veins at rear of wing (anal veins); small moths. Fig. 261. *Pyralididæ*

13. Hind wing with one or two complete anal veins; generally medium or large moths 14

14. First vein below the large central cell (discal cell) of fore wing apparently divided into three branches near end of cell 15

14. Same vein apparently divided into four branches 16

262.—Notodontid.

263.—Geometrid.

264.—Arctiid.

15. Hairy moths with thick thorax and abdomen; femur of legs clothed with long hairs. Fig. 262. (Prominents.) *Notodontidæ*

15. Slender bodies with broad delicate wings; legs without long hairs. Fig. 263. (Measuring worms.) . . *Geometridæ*

16. Stout moderate sized hairy moths; the wings marked in bold design of bright contrasting colors (a few forms plain white or yellow); first vein below discal cell of hind wing apparently four-branched. Fig. 264. (Tiger moths.) *Arctiidæ*

16. Wings dull gray or brown, or if bright colored the first vein below discal cell of hind wing is apparently three-branched (if wings are pure white tip of abdomen bears golden hairs) 17

265.—Lymantriid.

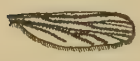
266.—Noctuid.

17. Margins of wings rounded; antenna usually feathery; first vein below discal cell of hind wing apparently four-branched. Fig. 265. (Tussock moths.) *Lymantriidæ*

17. Margins of fore wing nearly straight; antenna usually thread-like; first vein below discal cell of hind wing apparently three-branched. Fig. 266. (Owlet moths.) . . . . . *Noctuidæ*

KEY TO FAMILIES OF THE ORDER **DIPTERA**

267.—Crane fly.



268.—Mosquito wing.

1. Antenna long (of more than six segments), thread-like or feathery 2

1. Antenna short (of less than six segments), often fleshy 6

2. Usually large or medium sized insects with very long legs; a V-shaped furrow on top of mid-thorax. Fig. 267. (Crane flies.) . . . . . *Tipulidæ*

2. Small insects; without V-shaped furrow 3

269.—Cecidomyiid.

270.—Chironomid.

271.—Buffalo gnat.

272.—Horse fly.

273.—Robber fly.

274.—Bee fly.

275.—Syrphid.

3. Margin of wings and veins fringed with flat scales. Fig. 268. (Mosquitoes.) *Culicidæ*
3. Wings not fringed with scales (wings sometimes with scattered fine hairs).. 4
4. Only three wing veins; antennal segments usually bearing whorls of hairs. Fig. 269. (Gall gnats.)..*Cecidomyiidæ*
4. At least four wing veins..... 5
5. Antenna long and usually plume-like; abdomen slender; veins in lower part of wing indistinct. Fig. 270. (Midges.) *Chironomidæ*
5. Antenna shorter than thorax, not plume-like; body stout; wings broad. Fig. 271. (Buffalo gnats.) .....*Simuliidæ*
6. Terminal segment of antenna composed of 4 to 8 rings and tapering toward tip; head broad and sharply cut off at rear margin. Fig. 272. (Horse flies.) *Tabanidæ*
6. Antenna of not more than three segments, terminal segment not composed of rings; head rounded at rear margin 7
7. Second vein (Radius) below front margin of wing four-branched..... 8
7. Radius vein three-branched..... 9
8. Top of head sunken between eyes; body long and bristly; legs long. Fig. 273. (Robber flies.) .....*Asilidæ*
8. Top of head not sunken; body usually short and hairy; beak long and slender. Fig. 274. (Bee flies.).....*Bombyliidæ*
9. A vein paralleling margin of wing from apex nearly half around lower side of wing; usually an extra unbranched long vein between Radius and the next branched vein below it (Media). Fig. 275. (Hover flies.).....*Syrphidæ*
9. No vein paralleling lower margin of wing; no extra vein below Radius....10

276.—Bot fly.

277.—Anthonyiid.

278.—Tachinid.

279.—Sarcophagid antenna.

280.—Muscid antenna.

281.—Trypetid wing.

282.—Drosophilid.

283.—Scatophagid.

10. With no mouthparts, palpi absent; wing veins indistinct; bee-like. Fig. 276. (Bot flies.) ..... *Œstridæ*
10. Mouthparts well developed, palpi present; wing veins distinct..... 11

11. Small slender bright green flies with long legs ..... *Dolichopodidæ*
11. Not such flies..... 12

12. A prominent whitish thin lobe below base of wing; furrow across top near rear of thorax..... 13
12. Without prominent lobe below base of wing; without furrow across top of thorax 16

13. Cell below last branch of Radius (R5) closed or narrowed at margin of wing 14
13. Cell R5 widely open at outer end. Fig. 277. (Root maggot flies.) *Anthomyiidæ*

14. Antennal bristle bare. Fig. 278. (Tachina flies.)..... *Tachinidæ*
14. Antennal bristle hairy at least at base 15

15. Antennal bristle hairy at base, bare near tip. Fig. 279. (Flesh flies.) *Sarcophagidæ*
15. Antennal bristle entirely hairy. Fig. 280. (House flies.)..... *Muscidæ*

16. Wings spotted or banded with bark colored areas. Fig. 281. (Fruit flies.) *Trypetidæ*
16. Wings clear or with inconspicuous spots 17

17. Very small yellowish flies frequenting over-ripe fruit. Fig. 282. . *Drosophilidæ*
17. Medium sized slender flies clothed with yellowish hair. Fig. 283. . *Scatophagidæ*

KEY TO FAMILIES OR SUPERFAMILIES OF THE ORDER HYMENOPTERA

284.—Ant.

1. Wingless or winged; slender abdominal petiole having a sharp hump on its upper side. Fig. 284. (Ants.) *Formicidæ*
1. Winged or wingless; without hump on petiole 2

285.—Mutillid.

2. Wingless or winged; thorax or wide band across abdomen densely covered with reddish hair; hind tarsus slender and cylindrical. Fig. 285. (Velvet ants.) ..... *Multillidæ*
2. Winged; without covering of reddish hairs (or if with red hairs hind tarsus broad and flat)..... 3

286.—Bee.

3. Hind leg with basal segment of tarsus flattened for carrying pollen. Fig. 286. (Bees.) ..... *Apoidea*
3. Hind leg with tarsus rounded..... 4

287.—Wasp.

4. Fore wings folded lengthwise when at rest causing them to appear very narrow; (wasps). Fig. 287..... *Vespidæ*
4. Fore wings not folded..... 5

288.—Sawfly.

5. Abdomen joined broadly to thorax. Fig. 288. (Sawflies, horn tails.) *Tenthredinoidea*
5. Abdomen joined to thorax by slender petiole 6

289.—Ichneumonid.

6. Lower side of abdomen either sunken or with sharp keel along middle line; antenna longer than head and thorax; females with long slender ovipositor. Fig. 289. (Parasitic wasps.) *Ichneumonoidea*
6. Lower side of abdomen rounded or flat but never sunken or keeled; antennæ usually curled 7

290.—Sphecid.

7. Petiole long and easily seen from above. Fig. 290. (Thread waisted wasps.) *Sphecidæ*

7. Petiole short not easily seen from above 8

8. Body short and bee-like; color blue, green or violet; surface roughened by pits. (Cukoo wasps.).....*Chrysididæ*
8. Not such insects..... 9

291.—Spider wasp.

9. Legs very long (hind femur reaching almost to tip of abdomen); body usually dull dark color and wings smoky. Fig. 291. (Spider wasps.) (Pompilidæ.) *Psammocharidæ*
9. Legs short; body usually shining and often striped with yellow and black..10

292.—Scoliid.

10. Tip of abdomen sharp-pointed and bent abruptly downward or with a curved sting; a constriction on lower side between first two segments after the petiole of abdomen. Fig. 292. (Underground stingers.) .....*Scoliidæ*
10. Tip of abdomen bent gradually or straight; abdomen not constricted...11

293.—Bembicinæ.

294.—Cynipid.

11. Yellow bands across abdomen broken along middle of back; wasp like; often large insects. Fig. 293. (Cicada killer, fly killers.) Bembicinæ.....*Sphecidæ*
11. Small brownish hump-backed insects with thick abdomen and long usually straight antenna. Fig. 294. (Gall wasps.) .....*Cynipidæ*

B. LARVÆ

KEY TO ORDERS OF SOME COMMON LARVÆ

1. Aquatic, with tufts of hair-like filaments (for aquatic respiration or swimming) Figs. 303, 305, 306, or with a very long extensile lower lip, Fig. 302, or living in a tubular case under water, or legless 10
1. Not such larvæ, usually terrestrial or arboreal 2

2. Head easily distinguished..... 4
2. Head apparently not formed, no legs present on thorax..... 3

295.—Bee grub.

3. White or yellow soft grubs found in neat cells provided with pollen or insects as food. Fig. 295. (Grubs of bees and wasps.) .....*Hymenoptera*
3. White or colored larva usually pointed at one end; found in dead organic matter or among plant lice. (Fig. 296. (Fly maggots.) .....*Diptera*

296.—Fly maggot.

4. Well developed abdominal legs..... 5
4. Without abdominal legs..... 6

5. Less than six pairs of abdominal legs, each leg with a row of hooklets on the end. (Caterpillars.).....*Lepidoptera*
5. Six or more pairs of abdominal legs, no hooklets on end; caterpillar-like in form; eye spot on side of head. Fig. 297. (Sawfly larvæ.).....*Hymenoptera*

297.—Sawfly larva.

6. Thoracic legs present..... 7
6. Without thoracic legs..... 8

298.—Neuroptera.

299.—Bibionid.

300.—Flea larva.

7. Jaws longer than the head, sharp and curved, protruding forward prominently; body usually tapering at both ends. Fig. 298.....*Neuroptera*
7. Jaws usually shorter than the head and not especially prominent; bodies of various forms .....*Coleoptera*
8. Small slender white footless larva found in soil or in decaying organic matter; if head is black (Mycetophilidæ, Bibionidæ, Ryphidæ). Fig. 299....*Diptera*
or if head is lighter in color and mouthparts well developed. Fig. 300. (Fleas.) .....*Siphonaptera*
8. Not such larvæ..... 9
9. Thorax thick and muscular; head not prominent; jaws brown and sharpened for boring into wood. Fig. 326. (Borers.) .....*Coleoptera*
9. Body soft and fat, tapering at both ends, usually curved; grubs of *Hymenoptera* or weevils. Fig. 331..*Coleoptera*
10. No legs present.....*Diptera*
10. Thoracic legs present.....11

301.—Caddis worm.

11. Caterpillar-like; a single pair of abdominal legs at end of body, each with a hook; usually found at bottom of stream in a case made of sand, sticks, silk, etc. Fig. 301. (Caddis worms.) *Trichoptera*
11. Not such larvæ.....12

302.—Dragon-fly naiad.

12. A long extensile lower lip; abdomen broad; no hair-like filaments or tails; body smooth. Fig. 302. (Dragon-fly larvæ.) .....*Odonata*
12. Not such larvæ.....13

303.—Stone-fly naiad.

13. Tufts of hair-like filaments on sides of thorax behind each leg; no filaments on sides of abdomen; a pair of bristle-like tails at rear end. Fig. 303. (Stone-fly larvæ.) .....*Plecoptera*
13. Not such larvæ.....14

304.—Helgramite.

14. Two or three broad and leaf-like or feather-like tails; with or without filaments along sides of abdomen, none on thorax 15

14. No broad tails, but with filaments or prominent appendages along sides of abdomen; jaws sharp. (*Gyrinidæ, Haliplidæ* Fig. 329) *Coleoptera.* (Helgramite, *Sialidæ* Fig. 304). *Neuroptera*

305.—Damsel-fly naiad.

15. Three leaf-like tails, abdomen slender with no side filaments. Fig. 305. (Damsel-fly larvæ.) ..... *Odonata*

306.—May-fly naiad.

15. Abdomen with many hair-like filaments extending along its sides and two or three feathery tails at the end. Fig. 306. (May-fly larvæ.) .... *Ephemerida*

KEY TO THE FAMILIES OF SOME LEPIDOPTEROUS LARVÆ COMMONLY FOUND ON PLANTS

(Not including leaf-miners or case bearers)

307.—Measuring worm.

1. Five pairs of abdominal legs present (include those on rear end) 2
1. One to three pairs of abdominal legs; locomotion by looping. Fig. 307. (A few *Noctuidæ* and the measuring worms.) ..... *Geometridæ*

2. Very large caterpillars over 3 inches long when full grown 3
2. Smaller caterpillars under 3 inches long 4

308.—Sphingid.

3. A horn (or rarely an elevated spot) on top of segment 11. Fig. 308. . *Sphingidæ*

309.—Saturniid.

310.—Arctiid.

311.—Hesperiid.

312.—Lycænid.

313.—Papilionid.

314.—Tortricid.

315.—Pierid.

316.—Notodontid.

317.—Tussock caterpillar.

3. No horn or spot on top of segment 11 but often with numerous spines or spots of various colors scattered over the body. Fig. 309.....*Saturniidæ*
4. Medium sized caterpillars thickly covered with hair. Fig. 310...*Arctiidæ*
4. Bare or with hairs scattered..... 5
5. A distinct small neck joining head and thorax. Fig. 311.....*Hesperiidæ*
5. Head joined to thorax without a distinct narrow neck 6
6. Larva flat and oval with head retracted into body; legs very short; slug-like. Fig. 312.....*Eucleidæ, Lycænidæ*
6. Not such larvæ..... 7
7. Smooth large caterpillars with slit on top of prothorax from which when disturbed two scent glands are pushed out. Fig. 313 .....*Papilionidæ*
7. Not such insects..... 8
8. Small very active slender larvæ in a leaf rolled or folded and tied with silk. Fig. 314 .....*Pyralididæ, Tortricidæ*
8. Not such larvæ..... 9
9. Smooth green velvety larvæ often with narrow stripes; feeding openly by day on leaves of *Cruciferæ* (cabbage, etc.) and *Leguminosæ* (clover, etc.). Fig. 315 .....*Pieridæ*
9. Not such larvæ.....10
10. Medium sized larvæ, without legs on last segment of abdomen, often with prominent horns or patches of color; have habit of waving rear end of body in air; often gregarious. Fig. 316. *Notodontidæ*
10. Not such larvæ.....11
11. Prominent tufts of long hairs extending out from body (*Acronycta, Noctuidæ*), or tussock caterpillars. Fig. 317. *Lymantriidæ*
11. Not such larvæ.....11

318.—Noctuid.

319.—Nymphalid.

12. Smooth plump, greasy caterpillars usually with sombre stripes or spots; hiding by day and feeding by night. Fig. 318.....*Noctuidæ*

12. Brightly colored medium sized larvæ with a few long spines or branched hairs. Fig. 319 .....*Nymphalidæ*

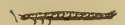
TABLE FOR DISTINGUISHING SOME COMMON COLEOPTEROUS LARVÆ

320.—Scarab.

1. Thick fat white grub with dark thoracic legs and head; body curved. Fig. 320. If in solid wood, *Lucanidæ*, otherwise *Scarabaeidæ*

321.—Tenebrionid.

2. Body long, slender, cylindrical, hard and shining; rear end with 2 prominent hooks. Fig. 321.....*Tenebrionidæ*



322.—Pyrochroid.

3. Same except body is flat; found in old tree trunks. Fig. 322.....*Pyrochroidæ*

323.—Wireworm.

4. Body long, slender, cylindrical hard and shining; rear end without prominent hooks. Fig. 323. (Wire worm.) *Elateridæ*

324.—Melandryiid.

5. Elongate, slender, white, cylindrical body with a pair of dark and prominent hooks on rear end; found in decaying wood. Fig. 324.....*Melandryidæ*

325.—Flat-headed borer.

6. Footless white larva; thorax much broader and flatter than rest of body; jaws dark and sharp; bores in wood. Fig. 325. (Flat-headed borers.) *Buprestidæ*

326.—Round-headed borer.

7. Same except that thorax is not so flat. Fig. 326. (Round-headed borers.) *Cerambycidæ*

327.—Carabid.

328.—Dytiscid.

329.—Gyrinid.

330.—Coccinellid.

331.—Weevil.

332.—Dermestid.

333.—Chrysomelid.

8. Body elongate, hard dark plates on top; two bristles on rear end; jaws sharp and prominent; usually found on the ground under shelter. Fig. 327.....*Carabidæ*
9. Body elongate; jaws prominent; abdomen pointed and with a few hairs or filaments along the sides; aquatic. Fig. 328 .....*Hydrophilidæ, Dytiscidæ*
10. Small slender aquatic larva with many projecting appendages along sides of abdomen. Fig. 329. *Haliplidæ, Gyrinidæ*
11. Flat oval scale-like larva clinging to lower side of stone in rapid stream (water penny)....(*Dryopidæ*) *Parnidæ*
12. Small warty or spiny body tapering at rear end; legs long; color usually black or blue with orange or red spots; found on green plants. Fig. 330. .*Coccinellidæ*
13. Small curved footless fat larva. If found under bark of trees in systems of tunnels *Scolytidæ* (Ipidæ). If in blossoms, seeds, fruits, twigs, etc. Fig. 331. (Weevils) .....*Curculionidæ*
14. Small larva covered with long hairs; usually in animal products. Fig. 332. *Dermestidæ*
15. Small white or colored larva; abdomen usually fat; head and thoracic legs well developed; found eating foliage or roots of plants. Fig. 333.....*Chrysomelidæ*

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